HYGIENE

AND

PUBLIC HEALTH

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WITH 77 ILLUSTRATIONS AND DIAGRAMS

THIRTEENTH EDITION, REVISED AND ENLARGED

CASSELL AND COMPANY, LIMITED
LONDON, NEW YORK, TORONTO AND MELBOURNE
1919

614
W587

First Edition *August* 1890.
Revised *January* 1893, *December* 1893, 1894, 1895, 1896, 1897, *January* 18
Reprinted *October* 1899.
Revised *June* 1901. Reprinted 1902, 1904.
Revised 1905.
Revised *March* 1908 Reprinted *September* 1908.
New and Enlarged Edition *September* 1911.
New and Enlarged Edition *September* 1917. Reprinted 1919.

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PREFACE TO THE THIRTEENTH EDITION

As, owing to unavoidable circumstances, Sir Arthur Whitelegge has been unable to take any share in the revision of the present edition, the task has fallen entirely to me, and has had to be undertaken in a somewhat scanty leisure. The book has, however, been thoroughly revised, and while certain portions have been curtailed or excluded, new sections have been added. A number of fresh illustrations have also been introduced, and much new material in regard to subjects which have assumed an increased importance, partly on account of the advance of Preventive Medicine and partly on account of the War. The application of the methods of Preventive Medicine to infant mortality, tuberculosis, venereal disease, and tropical diseases, and to military, naval, and industrial-welfare activities, has become more and more a matter of national urgency. Although, therefore, endeavour has been made to restrict the manual to its former size, an enlargement to the extent of some thirty-two pages was found to be necessary. It should be added that where competent authorities differ in opinion or practice, prominence has been given as far as possible to the official views generally accepted.

I may repeat that the object of this introductory and elementary manual is to summarize in a condensed and succinct form the most important applications of Preventive Medicine, for the use of the medical student, the medical practitioner, and the health officer in every branch of the Public Service. Such a review must necessarily be tentative and provisional in many ways. Improved methods and appliances, fuller and later statistics, the results of recent research, and new conceptions and applications are being brought forward almost continually. Nor must it be forgotten that, in addition to a considerable growth in our knowledge of the etiology of disease and the conditions of its progress and prevention, there is an ever-widening sphere of influence in the State both for the voluntary and the official worker in Preventive Medicine. The subject is thus year by year becoming of greater importance to the practitioner of medicine, and to all who are engaged in the Public Health Service.

GEORGE NEWMAN.

LONDON, *July*, 1917.

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CHAPTER I

AIR

THE primary essential requirement for the maintenance of life is air. In 100 volumes of pure dry air there are, approximately, 21 of oxygen, 78 of nitrogen, and 1 of carbonic acid, argon, helium, neon, krypton and xenon. There are also other gases in much smaller proportion. In practice, however, air is never quite pure or dry, and it is therefore necessary to include watery vapour, dust, and gaseous impurities of local origin.

Oxygen ranges from 20·99 per cent. by volume in sea or mountain air, to 20·7 in crowded rooms, 18·3 in ill-ventilated mines, and 16·5 in expired air. It is lessened by respiration, by combustion, by fermentation, by certain manufacturing processes, by oxidizable organic effluvia, and by fog; but it is increased by vegetation and by rain. The average in the open air of towns may be taken as 20·90 volumes per cent. The molecular formula is O_2.

Ozone, a more active and condensed form of oxygen, with the molecular formula O_3, instead of O_2, is an irrespirable gas readily reduced by oxidizable matter. It is only an occasional component of air, and is never present in more than minute traces, difficult of exact measurement. The proportion is greatest after thunderstorms, always higher on the sea coast than inland, and usually higher with S.W. than with N.E. winds. It is a powerful bleaching, oxidizing and disinfecting agent, and is used for purification of air and sterilization of water.

Nitrogen and argon are inert, and, from the point of view of public health, may be looked upon as diluents only.

Carbonic-acid gas (CO_2), said to be absent from desert air, varies from 2·5 per 10,000 in purest mountain or sea air, to 15 or 20 or more parts in 10,000 in confined atmospheres. In fresh open air it is stated to be, as a rule, 3 per 10,000, or 0·03 per cent. The proportion is greatly increased by expiration, for in expired air there is not infrequently as much as 450 parts per 10,000 (4·5 per cent.). The proportion of CO_2 in air is also increased by combustion, putrefaction, and fog, and it is diminished by vegetation, rain, high winds, and, in rooms, by ventilation. Both carbonic acid and organic matter are greater in the air of towns than in that of the country, and in day air than night air. In railway tunnels Clowes found an average of 14 parts of CO_2 per 10,000, and on one occasion as much as 28·8 parts. Inhabited rooms contain between 3 and 4 parts per 10,000, and anything above this amount should be regarded as impurity. CO_2 was taken by Pettenkofer as an index of atmospheric impurity, because it is more readily measured than some of the gases and organic matter by which it is accompanied when it is the product of respiration. Its presence is, of course, no indication of moisture, heat, or movement of confined atmosphere.

Ammonia salts in air, like carbonic-acid gas, are due mainly to animal exhalations and putrefactive processes. Fresh air contains from 0·03 to 0·10 mg.

of carbonate or nitrate of ammonia per cubic metre (1,000 litres), but in crowded rooms, or, for example, over middens, there may be 0·50 mg., or even more. The variations are generally parallel with those of carbonic acid, and are similarly affected by weather

Marsh gas or **methane** (CH_4) is met with in the air of coal mines (*fire-damp*) and marshes, and, in very small quantities, even in pure air. In the former case the proportion may be sufficient to destroy life by the exclusion of oxygen, but as much as 300 parts per 1,000 can be breathed with comparative impunity. If present in certain proportions it forms an explosive mixture with air. It is a constituent of coal gas.

Carbonic oxide (CO) is present in minute quantity in the air of towns, but in larger degree in, say, that of a railway tunnel. Coal gas contains from 4 to 12 per cent., but "water gas"* and "producer gas" as much as 40 per cent. Carbonic oxide is found as a product of imperfect combustion, particularly of charcoal, and cast-iron stoves or burners may give it off in considerable quantity. The inhalation of air containing 0·2 per cent. produces unconsciousness in half an hour, and 0·5 per cent. is rapidly poisonous. The toxic properties of carbon monoxide are due to the fact that the gas enters into direct combination with the hæmoglobin of the blood, forming with it an extremely stable compound, which acts as a narcotic poison. Persons thus poisoned die, therefore, simply from want of oxyhæmoglobin

Sulphurous acid (H_2SO_3) is another product of combustion, and traces of it are found in factory town air, least in clear breezy weather, most during fog and under anticyclonic conditions. Coal stoves and gas burning are the chief sources of SO_2 in the air of rooms.

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* Under various names gases of this nature are now largely made and supplied to the public, both separately and as an auxiliary to an ordinary coal-gas supply. They have, naturally, little lighting power, but can be charged with oil-spray so as to be equal to ordinary gas, and for certain trade processes luminosity is not required. Their use calls for great care in gas fittings, and as a further precaution the gas should be "odorised," that is, charged with some strong-smelling substance. In certain Acts authorising works of supply for "Mond gas," a limit of 14 per cent. of CO is imposed.

Sulphuretted hydrogen (H_2S) may occur in the air of marshes, in and near excavations, in collections of refuse or decaying vegetable matter, in sewer gas, and in chemical works and their waste heaps.

The inhalation of H_2S is followed by more poisonous results than is commonly supposed. An atmosphere containing 0·7 to 0·8 of H_2S in 1,000 litres of air is dangerous to human life, while air containing 1 to 2 per 1,000 parts destroys it in a few minutes. When only minute quantities are present, vertigo, headache, and malaise are produced. Two types of poisoning occur, namely (1) that resulting in sudden death due to the action of H_2S on the respiratory nerve centres, and (2) that resulting in slow poisoning and death by asphyxia in addition to nervous phenomena.

It may here be stated that the various constituent parts of air are not chemically combined, but only mechanically mixed. The proofs of this are—(*a*) that the relative proportions of oxygen and nitrogen present in air are not those of their combining weights, or of any simple multiple of those weights; (*b*) that if air be artificially made by mixing oxygen and nitrogen together in due proportions, no change of volume or temperature takes place as would be found had chemical combination occurred; (*c*) that on diffusion there is a separation of the two chief gases, whereas a chemical compound would diffuse unchanged; and (*d*) that if air and water be shaken together the water dissolves some of the air, which can be subsequently expelled by boiling, when the air which is expelled will be found to contain 14 per cent. more oxygen, which signifies that the atmosphere is not a stable chemical compound.

Physical properties. 1. **Weight.**—At a temperature of 32° F., the barometer being at 29·9 inches, 100 cubic inches of air weigh about 32·5 grains, and a cubic foot 573 grains. 2. **Compression and expansion.**—The stratum of atmosphere near the earth's surface is more dense because more subjected to pressure than a stratum remote from the earth's surface. The air is subject to Boyle and Mariotte's law: *the temperature remaining the same, the volume of a given weight of air is inversely as the pressure which it bears.* Under extreme pressure, with very low temperature, we now know that it may be liquefied (*Dewar*). The converse of compression is also true, and air is capable, in common with other gases, of expansion. This, too, follows a law, that of Charles: *the volume of a given weight of air at a constant pressure varies directly as the absolute temperature.* The increase of the unit of volume of a gas for one degree of temperature, that is, from zero to one degree, is termed the *co-efficient of expansion*, and is practically the same for all gases ($\frac{1}{273}$ of their volume). For every degree Fahrenheit above 32° the co-efficient is $\frac{1}{491}$ part of its volume. 3. **Diffusion.**—If two different gases in receivers be brought into communication with each other, they will diffuse the one into the other, and similar diffusion occurs in the atmosphere, but all gases do not diffuse at the same rate. According to Graham's law *the rates at which gases diffuse vary inversely as the square roots of their densities.* These physical properties of air are of importance in connexion with the practice of ventilation.

The physiological effects of abnormal atmospheric pressures have recently received attention owing to the occurrence, in certain engineering enterprises, of **compressed-air illness** or **caisson disease.** Under increased atmospheric pressure (say 25 lb. to the square inch) a sense of fullness in the head occurs, accompanied by deafness, frontal headache, with or without epistaxis, sometimes hæmoptysis, and in all cases a degree of arterialization of blood in superficial veins. The symptoms of caisson disease are syncope, pains in limbs, epigastric pain, nausea and vomiting, and motor and sensory paresis. Rapid decompression is probably responsible for many of the symptoms. Twenty minutes for each atmosphere of pressure above the normal should be allowed for decompression, and during the period of decompression all parts of the body should be quietly exercised in order to maintain capillary circulation (*Greenwood*).

Bacteria in air vary in number and species according to certain external circumstances, of which the following are the chief, namely, (1) the pollution of the air, (2) the dampness of surrounding surfaces, (3) gravity, and (4) various seasonal and meteorological conditions.

1. **The pollution of air.**—It was Tyndall who in 1878 first pointed out that dust in air might carry micro-organisms ("the raft theory"), and that, other things being equal, dusty air contained more bacteria than dust-free air. Since that time many investigators have confirmed this by examination of the air of workshops, schoolrooms, etc. In open fields, free from habitations, few bacteria are present, and the same is true of mountain and sea air; in towns or crowded rooms the reverse is the case. Haldane found 8 per litre in a dressmaker's workroom, but 850 per litre in a dusty ropemaker's room; Graham Smith found 32 per litre in the dining-room of the House of Commons, and 1 per litre in the open air of the Terrace; and Andrewes, investigating the air of the Central London Railway (underground tube),

found 12 per litre on the lift and 21 per litre on the platform. An atmosphere may be offensive and yet comparatively free from bacteria, as in sewer gas, certain offensive trades, railway tunnels, etc.

2. **The dampness of surrounding surfaces.**—Air over sandy soils contains more bacteria as a rule than that over damp clay soils. Rain and snow diminish the number of organisms in air. It has also been proved that air contained within a moist perimeter is almost germ-free. Hence the comparative absence of bacteria in expired air in ordinary quiet respiration, though in the act of coughing, sneezing, or shouting organisms may be present in the expired air (*Flügge*). Haldane, Andrewes, and others have shown that the same principle applies in a sewer, the air of which frequently contains fewer organisms than that of outside air, the species found belonging less to the sewage than to outside air. This is also the explanation of the retention of bacteria in sputum (the tubercle-bacillus), or excreta (the typhoid bacillus), so long as these materials remain moist.

3. **The influence of gravity** operates upon microscopic cells in the same way, of course, as upon other particulate matter. Hence, fewer bacteria are found at high altitudes or on the tops of lofty buildings. Graham Smith found that at the top of the Clock Tower of the Houses of Parliament in London there was only about one-third of the number of bacteria found at ground level.

4. **Seasonal and meteorological conditions** also exert an influence upon the number of bacteria found in air. The seasonal maximum in the open air seems to occur about midsummer, and the minimum about the middle of winter, but in hospital wards and houses the reverse occurs, owing no doubt to ventilation. Air-currents and wind, of course, exert a marked influence, as also do rain and snow.

Direct sunlight possesses considerable bactericidal power, and thus reduces the number of air organisms.

Unlike the organic matter and carbonic acid, the number of microbes in the air of *crowded rooms* is dependent rather upon habitual uncleanliness than upon the conditions of ventilation at the time of observation. They are not due to ordinary respiration, nor as a rule to want of cleanliness of persons or clothing, but are derived from the walls, ceiling, and floor of the room itself, especially if these are porous and absorbent, and are so made as to vibrate and thus create dust. As to the nature of the microbes found in the air, little that is final can be said. Their variety is considerable, and for the most part they are saprophytes and harmless to man, but they may include putrefactive, suppurative, intestinal, and pathogenic organisms. Under exceptional conditions bacilli of tubercle, typhoid fever, and other diseases have been isolated from air, and Gordon has detected an "air streptococcus" and a "skin staphylococcus," indicative of filth and human pollution.

Spores of moulds, though more bulky than most other air-borne organisms, are less readily deposited. Other low forms of organisms and pollen may also be found, and may be the source of certain forms of disease (hay-fever).

Dust.—Aitken found the number of dust particles per cubic inch of air to range from 2,000 in the open country to 3,000,000 in towns, and 30,000,000 in rooms. Apart from living organisms, dust consists chiefly of mineral particles, and of formed or unformed organic matter of vegetable or animal origin, epithelium scales, pollen, or particles of flax, wool, or cotton.

Indoor dust contains more organic components than that of the open air, although open fires add largely to the mineral part. The heavier particles subside readily in still air, the lighter more slowly, but practically deposition is always taking place, even in closed rooms and spaces, since air carrying dust is constantly passing in or out through crevices with variations of temperature and pressure. Hence the only dust-proof spaces are those which are kept hermetically sealed or in which there is provision for free entry of air through a dust-filter. The inhalation of dust may lead to various forms of pulmonary disease—anthracosis, silicosis, etc. Tuberculosis is spread in this way. Limestone and plaster-of-Paris dust are relatively innocuous; but silica, owing to physical and chemical properties, is highly injurious (*Collis*). Lead dust and the dust of T.N.T. and its derivatives are also poisonous (*see* pp. 682, 684).

Respiration.—The oxygen of the air, taken into the lungs by inspiration, passes by osmosis in the air-cells into the blood-capillaries and there unites with the *hæmoglobin* of the blood as *oxyhæmoglobin*, in which form it is carried throughout the body. The tissues abstract the oxygen, and, as a result of oxidation, yield CO_2, which finds its way back to the lungs in the venous blood. Thus expired air possesses 4 per cent. of CO_2 in place of 4 per cent. of oxygen. Water, organic matter, and a little ammonia are also added. An average adult gives off about 0·6–0·8 cubic foot * of carbonic acid per hour, or 17 litres, of which perhaps about one-fiftieth part is yielded by the skin (*Regnault*). Haldane gives the amount as 0·6 cub. ft. for a man at rest, and 1·1 during work. The amount is less in women, children, and aged persons, but more in animals, such as oxen or horses, which give off about three times as much CO_2 as does man.

Expired air, as we have seen, contains about 4·5 per cent. of carbonic acid, and only about 16 per cent. of oxygen. As a rough average it may be stated that 9–10 oz. of watery vapour are given off by the human lungs in 24 hours, and 20–25 oz. by the skin. In health, expired air contains few, if any, microbes, but much organic matter. It is nitrogenous, oxidizable, molecular, and probably exists in combination with water, since it is readily absorbed by hygroscopic objects. It is precipitated from solution by silver nitrate, blackens on ignition, reduces potassium permanganate, yields ammonia on distillation with alkaline permanganate, and has a fetid smell. Unlike carbonic acid, organic matter diffuses sluggishly through the air of a room, and is destroyed slowly by fresh air. It promotes the growth of micro-organisms, in which respect it appears to differ from CO_2; and milk, meat, or other foods in contact with it readily become tainted. The production per head of both carbonic acid and organic matter is increased after physical exercise. At rest a man breathes 7 litres of air and uses 300 c.c. of oxygen per minute, but in vigorous muscular work he may breathe upwards of 100 litres of air and use 3,000 c.c. of oxygen.

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* 0·56 during sleep; 0·78 when awake. (*Pettenkofer.*)

Combustion. — Coal when burnt gives off — (1) carbonic acid, together with carbonic oxide unless the combustion is complete; (2) sulphurous and sulphuric acids (1–5 per cent. sulphur exists in coal), carbon bisulphide, ammonium sulphide, and sometimes sulphuretted hydrogen; (3) water; (4) fine particles of carbon and tarry matter.

Coal gas yields similar products, but there is little free carbon or organic matter. The sulphur in gas should not exceed 20 grains per 100 cub. ft. The Alkali Works Regulation Act (1906) provides that not more of the acid gases of sulphur and nitrogen than the equivalent of 4 grains of sulphuric anhydride per cubic foot of air, gas, or smoke must escape into the atmosphere. Wood yields little of the sulphur compounds. Oil and candles give scarcely any, but they increase the organic matter in the air.

The gaseous products, especially carbonic acid, are rapidly diffused by air-currents; but the suspended particles diffuse slowly, and are not as a rule found at a greater elevation than 600 feet. Impurity from the use of illuminants also pollutes the air, and at the same time exhausts it. An ordinary bat's-wing burner (16 candle power), consuming 5½ cub. ft. of gas in one hour, has been estimated to produce 2·8 cub. ft. of CO_2 and 7·3 cub. ft. of moisture, thus vitiating the atmosphere to the extent which five adults would do in respiration. There is also abstraction of oxygen. On the other hand, the burning of gas may assist ventilation by causing increased circulation of air.

Impurities of air include micro-organisms, organic effluvia, fumes and gases, particulate matter and dust (poisonous or otherwise) The micro-organisms present, as already stated, are usually saprophytic, but may be parasitic and even infective. Organic effluvia result from factory processes, sewage, garbage, etc., and from various degrees of fermentation and decomposition. Of the gaseous impurities the chief are CO_2 and CO (derived from man and animals, from combustion, and trade processes), sulphur gases, and ammonia in combination or free. The particulate matter consists of organic and inorganic dust (spores, animal and vegetable cells, coal dust, etc.). The amount of organic matter is indicated (*a*) by sense of smell of a person coming in from the fresh air, (*b*) by measuring the amount of CO_2 by analysis, (*c*) by direct estimation of the organic matter itself. Speaking generally, the chemical impurities of the air (reduced oxygen, increased CO_2 and organic matter) are not now held to be the chief agents of its injurious capacity. Haldane, Hill, Flack, and others have shown that dust, bacterial infection, and particularly the physical characters of temperature, relative humidity, and movement of air, exert the principal effect. Hill has demonstrated that man can breathe air containing 3 to 4 per cent. of CO_2 and only 16 or 17 per cent. of oxygen without actual poisoning. Divers, caisson workers, and brewery-vat workers suffer no ill effects breathing air containing 2 per cent. CO_2. Relief is obtained by increasing the air motion by fans. Excess of CO_2 above 5 per cent. produces dyspnœa and headache in a few minutes, and higher percentages spasm of the glottis. The essential air conditions of adequate ventilation are therefore (1) cleanliness and freedom from dust, (2) movement, coolness, and relative moisture of the air, (3) reduction of bacterial pollution and absence of pathogenic organisms.

Examination of air.—1. **Particulate matter and bacteria** suspended in the air may be collected for microscopic examination by aspirating the air through water; or by allowing a jet of air to pass into an exhausted receiver through a fine aperture, so as to impinge upon glass smeared with glycerin, which arrests the particles (Pouchet's aeroscope); or by aspirating air through a filter of powdered sugar, and, by dissolving away the sugar in water, obtaining the intercepted particles available for examination. By measuring the volume of air aspirated, and counting the particles in an aliquot part of the intercepting material, these methods can be made quantitative.

Micro-organisms will, for the most part, escape detection by this method, and, indeed, no means exist of determining their number with accuracy. A rough approximation may be obtained by making a plate-cultivation from the whole (or an aliquot part) of the material obtained in the manner described above, and counting the colonies; but for obvious reasons the result gives only the number of organisms which can grow under one set of conditions. Hesse aspirates air slowly through a wide horizontal glass tube smeared on the inside with nutrient gelatin, the air entering through a pinhole at such speed as to allow suspended particles to fall upon the gelatin. Sedgwick, Frankland, Petri, Pasteur, and others have adopted methods of filtration through sugar, sand, etc., which is subsequently cultured in favourable media. The amount of air examined is measured by a syringe or aspirator of known capacity. Koch relied on exposure of plates of gelatin to the air to be examined. Gordon prefers using "broth-plates" in the same way, with anaerobic cultivation of the broth at 37° C. for 48 hours and subsequent subculture. Search should be made for streptococci (as indices of saliva), *B. coli* and *B. enteritidis sporogenes* (as index of recent and non-recent fæcal pollution), and *B. mycoides* (as index of soil contamination).

2. **Organic matter** in air may be measured by determining the volume of air required to decolorize a known volume of a standard solution of permanganate of potash, such as 0·316 grm. in 1 litre of distilled water. The air may be aspirated through the solution, or successive volumes washed with the permanganate, by shaking in a bottle until the solution is no longer pink (*Carnelly*). Another plan is to aspirate a known large volume of air through distilled water, and then examine the latter by Wanklyn's albuminoid ammonia process, described subsequently (p. 80). In such estimations it is desirable in each case to make control experiments.

3. **Carbonic acid.** (1) *Pettenkofer's method.*—The solutions required are: (*a*) Pure lime-water, saturated or nearly so; (*b*) standard solution of crystallized oxalic acid of such strength (2·25 grm. per litre) that 1 c.c. exactly neutralizes 1 mg. of lime, CaO. From the equation

$$\underset{56\text{ mg.}}{CaO} + \underset{44\text{ mg.}}{CO_2} \Longrightarrow \underset{100\text{ mg.}}{CaCO_3}$$

it is evident that 1 mg. of CaO takes $\frac{44}{56}$ mg. of CO_2. The volume of 44 mg. of CO_2 at 0° C. and 760 mm. pressure is 22·4 c.c., so that $\frac{44}{56}$ mg. $= 0·4$ c.c. Hence, each c.c. of oxalic solution corresponds to 0·4 c.c. of carbonic acid, either being capable of neutralizing exactly 1 mg. of lime.

A wide-mouthed glass bottle, provided with a tight-fitting glass or rubber stopper, is also necessary. Its capacity should be about 5 litres, and must be determined accurately.

The bottle, having been cleaned and *dried*, is filled with sample air, either by means of a bellows, or other dry method. Moisture is held to invalidate the result. Clear lime-water, 60 c.c., is put into the bottle, the stopper is inserted, and the air thoroughly washed with lime-water by means of vigorous shaking. The carbonic acid combines with lime and forms a milky precipitate of carbonate of lime; the loss of strength of the lime-water therefore measures the amount of carbonic acid present. After the bottle has stood at rest for a few hours, 30 c.c. of the lime-water is removed for analysis. It is not possible to collect the whole of the 60 c.c., nor would there be any advantage in doing so.

It only remains to determine by means of the oxalic solution the amount of lime present in the lime-water before and after the process, and from the loss to calculate the proportion of carbonic acid in the known volume of sample air. The determination of the "causticity" of the lime-water (that is, the amount of caustic lime it contains) is made by a simple process of alkalimetry. Oxalic solution is dropped from a graduated burette into a measured quantity (30 c.c.) of lime-water, until the exact point of neutralization is reached. Several "indicators" are available for the recognition of this point. If a drop of the lime-water is removed from time to time and put upon turmeric paper, it will give a brown stain as long as any caustic lime remains unneutralized, but none when the neutralization is complete. A still simpler indication is obtained by adding to the lime-water a few drops of a solution of "phenolphthalein," which is decolorized as soon as all the lime is neutralized.

Example.—The capacity of the bottle is 4,840 c.c., and 30 c.c. of lime-water take respectively 38 and 31 c.c. of oxalic solution before and after the process.

The volume of air is 4,840 c.c. – 60 c.c. = 4,780 c.c. Since 30 c.c lost 7 mg. of lime, the 60 c.c. employed lost 14 mg., and from data already given this corresponds to $14 \times 0·4 = 5·6$ c.c. of carbonic acid. Hence, the sample air contained (by volume) 5·6 parts of carbonic acid in 4,780 of air, or 1·17 per 1,000.

Corrections must be made if the temperature deviates materially from 32° F., or the barometric pressure from 30 in. of mercury. One per cent. should be added to the result for every 5° above 32° F. If the barometric reading is B, the result must be multiplied by $\frac{30}{B}$. Thus, if in the above example the temperature were 72° F., and the pressure 29·2 in, the corrections would be as follows:—

$$1·17 \times \frac{108}{100} \times \frac{30}{29·2} = 1·3 \text{ parts of carbonic acid per 1,000.}$$

(2) *Haldane's method.*—A method has been devised by Haldane for determining CO_2 without using collecting jars, etc. He adapts a gas analysis apparatus consisting of a burette with a wide ungraduated portion and a narrow portion graduated in divisions of $\frac{1}{10000}$ part of the capacity of the

burette. This is enclosed in a water jacket, and a control tube is used to correct for variations of temperature. The pressures under which the readings are made are found to be the same, before and after absorption, by measuring the level of the potash solution in the narrow tube. The graduated burette allows of 25 c.c. of air to be admitted for examination. The amount of air having been collected, the CO_2 is absorbed in the caustic potash solution. After complete abstraction of CO_2 the volume of the air is again read off at the same temperature and pressure. The difference between the two readings gives the result in volumes of CO_2 per 10,000 of air

(3) *Angus Smith's minimetric method or "household" test.*—A certain amount of carbonic acid is needed in order to produce a cloud in a given volume of lime-water. The volume of lime-water being constant, the volume of air necessary to give a visible precipitate affords a simple inverse measure of the carbonic acid it contains. Half an ounce of clear lime-water is placed in each of a series of stoppered bottles of different sizes, and well shaken. The *smallest* bottle which shows any cloudiness indicates the proportion of carbonic acid present in the sample air, according to the following empirical scale :—

A ppt. in a bottle of	443	c.c. capacity indicates the presence of at least	0·4	parts CO_2 per 1,000.
,,	356	,, ,,	0·5	,,
,,	299	,, ,,	0·6	,,
,,	259	,, ,,	0·7	,,
,,	228	,, ,,	0·8	,,
,,	204	,, ,,	0·9	,,
,,	185	,, ,,	1·0	,,
,,	157	,, ,,	1·2	,,
,,	128	,, ,,	1·5	,,
,,	100	,, ,,	2·0	,,

Adopting 0·6 per 1,000 as the permissible limit of carbonic acid, there should be no precipitate when half an ounce of lime-water is shaken in a bottle of 300 c.c. or 10½ oz. capacity. The method is not very satisfactory or accurate.

4. **Carbonic oxide** may be determined quantitatively by eudiometry, or by exposing a measured volume of air to a solution of cuprous chloride, which absorbs this gas. The loss in volume shows the amount of carbonic oxide present. On passing CO through palladium chloride solution a black precipitate of carbon is formed; or through iodic acid, when iodine is liberated. Its presence may also be determined by Vogel's blood-test with the spectroscope. A caged mouse is affected in 1½ minutes by air containing 0·4 per cent. of CO, and this may be used as a sensitive test (*Haldane*).

5. **Oxygen** is determined quantitatively by exposing a measured volume of air to a solution of alkaline potassium

pyrogallate, which absorbs the oxygen. The analysis may be conveniently made in a graduated glass tube inverted over a mercurial trough; the tube having been filled with air, the pyrogallate solution is passed up into it through the mercury. All the readings must be taken at the same pressure. Oxygen may also be determined by a Hempel burette and pipette, using phosphorus as the absorbent; or by tests showing its power of supporting combustion.

6. **Ozone** is detected by its action upon potassium iodide. Strips of porous paper are steeped in a solution containing starch and potassium iodide, and then dried. These are exposed for a definite period to the air, care being taken to exclude sun and rain. Ozone causes a blue tint, the intensity of which is taken as indicating the amount of ozone, according to a standard scale of tints;[*] the ozone liberates iodine from the potassium iodide, and the iodide strikes a blue colour with the starch. Neutral litmus and pure potassium iodide may also be used. This paper is coloured blue at once by air containing $\frac{1}{300,000}$ of its weight of ozone, and slightly blue by from 0·0002 to 0·0003 mg. of ozone. Wurster's reagent (tetramethyl-paraphenylene-diamine) may be similarly used.

7. **Ammonia** may be collected by aspirating a known volume of air through distilled water, and then determined (quantitatively as well as qualitatively) by Nesslerizing (p. 81).

8. **Nitrogen** is determined with sufficient accuracy as the residue left when oxygen is removed by pyrogallate solution. The proportions of other gases are so small that their retention does not materially affect the determination of nitrogen.

9. **Water,** or rather aqueous vapour in air, may be measured by the hygrometer, by the spectroscope, or volumetrically by its absorption by sulphuric acid, chloride of calcium, etc.

It may be necessary occasionally to test for sulphuretted hydrogen, or for mineral acids due to chemical manufacturing processes. The former is detected by exposing strips of porous paper moistened with a solution of lead acetate, and noting the black colour due to formation of lead sulphide. Free mineral acids will redden moist blue litmus paper; and may be obtained for chemical analysis by aspirating the air through distilled water or solution of caustic potash.

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[*] For several reasons this test is held to be inexact. The chief are—(1) that chlorine and nitrogen tetroxide, as well as ozone, give the reaction; (2) that the conditions of exposure are not uniform—light, wind, humidity, and temperature all vary, and all affect the reaction; and (3) that some of the liberated iodine is volatilized, and some reacts again upon the potash to form inert iodide and iodate.

CHAPTER II

METEOROLOGY

THE principal climatic phenomena requiring systematic record are the temperature of the air, atmospheric humidity, atmospheric pressure, movements of the air, rainfall and climate.

1. **Temperature** varies constantly in regard both to space and time, so that the reading at any one time or in any one place has only a limited significance. Maximum and minimum registering thermometers are required for systematic record.

The *maximum thermometer* has a mercurial column, a detached portion of which serves as an index, being either permanently separated from the rest by a minute bubble of air (Phillips), or else detached afresh each time by means of a constriction near the bulb (Negretti), which allows the expanding mercury to pass, but renders the cohesion of the metal insufficient to draw it back upon cooling. The thermometer is kept horizontal, and the index is shaken back after each reading, ready for a new observation.

The *minimum thermometer* (Rutherford's) contains coloured alcohol. The index is a little metal rod included in the column, and is drawn back by capillary attraction as the column contracts, but allows the alcohol to flow past it when expanding. To set the instrument, it is only necessary partially to invert it, and let the index fall to the top of the spirit column. It is then replaced in the horizontal position.

If the instruments are read once daily, say at 9.0 a.m., they indicate respectively the highest and lowest temperatures attained during the previous 24 hours, irrespective of the time of occurrence.

Two sets of instruments are used, one for "shade" temperatures, i.e. the temperature of the air itself, the other for "radiation" temperatures with free exposure to the sun.* Thus are obtained, for each day, shade maximum, shade minimum, sun maximum, grass minimum; and from these may be recorded the daily, weekly, monthly, or yearly ranges, both in shade and with free radiation.

The **mean temperature** of the day is calculated—

(*a*) By taking the mean of the maximum and minimum recorded temperatures. This is correct only in winter; at midsummer it is often more than 2° too high.

(*b*) By taking the mean of two readings at twelve-hour intervals: e.g. 9.0 a.m. and 9.0 p.m.

(*c*) By using the Kaentz-Lloyd formula: Min. $+$ (max. $-$ min.) $\times$ 0·41 $=$ mean temperature.

(*d*) By taking hourly readings, or a continuous record, by means of photography. The mean of these is the true mean temperature of the day.

The weekly, monthly, and annual means are the averages of the daily means. Taking the average of a number of years, the daily minimum occurs at about 4.0 a.m., the maximum at 2.0 p.m. The annual extremes are in July and January respectively.

Temperature is interchanged by *conduction* (as in soils), *convection* (in fluids), or *radiation* (solar or terrestrial). Proximity to the sea lessens the range of temperature and moderates its extremes. Elevation lowers the temperature, by facilitating radiation. The influence of latitude, of winds and ocean currents, and of aspect and exposure, is obvious. Some soils are "hot"—dry sands and hard rocks, for example—while moist clayey soils are "cold." A surface covered with vegetation radiates much more rapidly than bare earth; at night a grass field is colder

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[*] The former are placed in a louvred wooden box, 4 ft. above the ground. The "sun-maximum" or "solar-radiation" thermometer also is placed 4 ft. above the ground; it has a blackened bulb, which is enclosed in a second glass bulb exhausted of air. The corresponding minimum instrument is supported upon a little wooden tripod, close to the ground.

than a road. The radiation thermometers are affected principally by the degree of sunshine and the humidity of the atmosphere.* Equality of temperature is denoted on maps by means of *isothermal* lines, which broadly follow an east-and-west course. The mean temperature of Plymouth is 51·4° F., of London 50·4° F., of Edinburgh 47·1° F., and of Aberdeen 46·4° F.

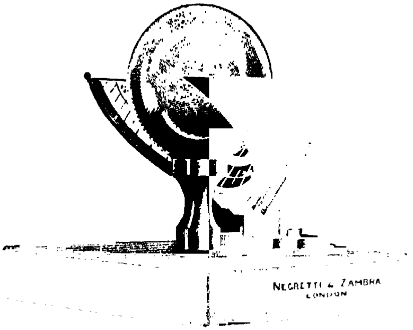

Fig. 1.—Campbell-Stokes' sunshine recorder.

Earth temperature—that is, the temperature of the soil at fixed depths—is more uniform and less diurnally variable than atmospheric temperature.

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* The duration and intensity of *sunshine* are recorded by Campbell-Stokes' or Jordan's apparatus. The former (Fig. 1) consists of a glass sphere, which acts as a lens, and brings the rays to a focus at successive points upon a curved sheet of paper placed at the right distance. A burnt track is thus described for such time as bright sunshine continues. Jordan's sunshine recorder is a small flat circular box. The sunshine is admitted through a slit, and impinges upon sensitized paper, leaving a varying photographic record of its duration and intensity. In either apparatus the papers must be renewed daily, and in the latter the sensitized paper must be "fixed" by immersing it in water. *Isohels* are lines denoting equal degrees of bright sunshine. The average number of hours of bright sunshine in the British Islands is about 1,400 per annum; in mid-Europe, 1,800; in Italy, 2,200; and in Spain, about 3,000. *Isonephs* are lines denoting equal cloudiness.

According to Ballard, when the temperature at 4 ft. reaches 56° F., infantile diarrhœa may be expected to become epidemic. Earth temperature, which is measured by Symonds' earth thermometer, varies but little, proportionately, from surface temperature, except that it is much more sluggish in variation. At 24 ft. of depth, however, it is almost the reverse of surface temperature, being highest in winter and lowest in summer (*Forbes*). Below 40 ft. there is little annual variation in the temperature of the soil.

2. **Atmospheric humidity** involves rather complex considerations. Water evaporates into dry air, as into a vacuum, but the volume of the resulting moist air is greater than that of the original dry air. For example, a cubic foot of dry air at 60° F. weighs 536·3 gr., and is capable of taking up 5·77 gr. of water; the product, however, is not 1 cubic foot of moist air, weighing 542·1 gr., but 1·0176 cubic foot, and a cubic foot of the same moist air weighs only 532·7 gr. At 32° F. a cubic foot of dry air can take up only 2·13 gr. of water; at 80° F. it can take up 10·98 gr. Further, the capacity for moisture increases with the temperature, but much more rapidly.

Indeed, it may almost be said that, comparing temperatures which increase in arithmetic progression, the capacity of dry air for moisture at those temperatures increases in geometric progression. Taking 0° F. as a starting-point, the capacity for moisture (in other words, the weight of a cubic foot of aqueous vapour) doubles with successive increments of temperature, not departing greatly from an arithmetic series.

Temperature (F.)	Weight of a cubic foot of vapour
0°	0·55 gr.
16°	1·09 ,,
33°	1·21 ,,
52°	4·89 ,,
73°	8·82 ,,
96°	17·68 ,,

As a rule, the water present in air is only about 70 or 75 per cent. of the amount required for saturation, but if the air is cooled the same quantity of aqueous vapour may suffice to saturate it; and if the cooling is carried further some of the water will be precipitated as mist or dew. It will be understood, therefore, that, however dry the air may be, it always contains a certain proportion of water, and if cooled to a certain temperature will be "saturated" by that moisture; this temperature is called the *dew-point.* "Super-saturated" air deposits its moisture only upon solid surfaces, and this is the cause of mists and fogs.[*]

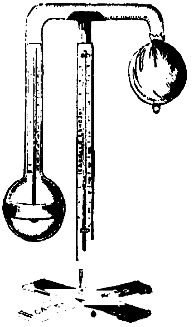
Fig. 2. - Daniell's hygrometer.

Humidity is measured by **hygrometers** of various kinds.

Daniell's (Fig. 2), now rarely used, consists of two dependent glass bulbs, connected by a tube bent twice at right angles. One bulb is of black glass, and contains a thermometer, the stem of which is visible in the tube above; the other bulb is covered with linen. Both bulbs contain ether. A little ether is dropped on the linen coating, and by its evaporation lowers the temperature of that bulb, so that ether distils over from the blackened bulb. This causes the temperature of the latter to fall; as soon as it sinks to the dew-point the black surface is dulled by deposit of atmospheric vapour, and this temperature is instantly read off by means of the contained thermometer.

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[*] *Fog* is formed by the condensation of watery vapour on dust particles suspended in the air, which afford "free surfaces" on which condensation can occur. Such atmospheric dust probably consists of fine salt dust from the sea, meteoric dust, condensed gases, combustion dust, and particulate organic and inorganic matter. Aitken holds that the earth's atmosphere is greatly polluted with dust, produced by human agency, rising by heated strata of the air, and forming the "free surface" for condensation, even though the air be not saturated. The higher the humidity and the higher the vapour tension, when the air is not saturated, the greater is the amount of moisture held by the dust particles. Town fogs and smoke fogs may be dry, and are largely constituted of particles of unconsumed carbon.

Regnault's is somewhat similar, but the black bulb is replaced by a more sensitive bright silver cup, and the distillation is brought about more conveniently and rapidly by means of aspiration of air through the ether.

Dines' (Fig. 3) consists of a plate of black glass, covering a small chamber containing the bulb of a thermometer. Cold water is passed through this chamber until the dew-point is reached and the glass becomes dull; the current is then stopped, the temperature gradually rises, and the thermometer is read

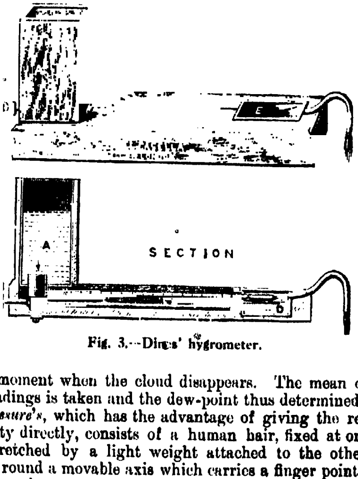

Fig. 3.—Dines' hygrometer.

at the moment when the cloud disappears. The mean of the two readings is taken and the dew-point thus determined.

Saussure's, which has the advantage of giving the relative humidity directly, consists of a human hair, fixed at one end and stretched by a light weight attached to the other. It passes round a movable axis which carries a finger pointing to a graduated arc. The hair, which must be uninjured and free from oil, elongates with moisture and contracts as it becomes dry; and in so doing rotates the axis and the indicator. The instrument has to be graduated empirically by exposing it first to perfectly dry air, and then to air saturated with moisture, and making the respective positions of the index the 0 and 100 points upon the graduated scale.

The *wet and dry bulb* hygrometer (Fig. 4) is usually employed. Two ordinary thermometers are fixed side by side, one of them having its bulb covered with muslin, kept wet with distilled water; a tail of the muslin dips into a vessel of water so as to make good the loss by evaporation. If the air is saturated with moisture, no evaporation takes place, and the two thermometers give the same reading. If it is not saturated, evaporation lowers the temperature of the wet bulb.

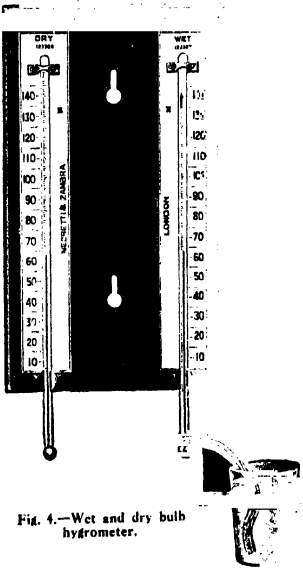

Fig. 4.—Wet and dry bulb hygrometer.

From the wet and dry bulb readings the *dew-point* can be calculated, and from the dew-point the weight of water present in the air. The dew-point is determined by calculation,* or, more conveniently, by reference to Glaisher's Tables,[*] in which the results are given for all ordinary values of both readings. The dew-point being known, the next step is to find the **relative humidity** of the air, which is that proportion of the total possible amount of aqueous vapour which the atmosphere at a given temperature actually holds. This is always expressed as the percentage of total saturation. For this purpose reference is made to hygrometric tables, giving the weight of a cubic foot of vapour at each temperature; and the relative humidity =

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* By the use of Apjohn's Formula, $f'' = f' - \frac{t - t'}{87}$, where t and t' are the dry and wet bulb readings respectively, f' the elastic tension of vapour corresponding to t' (as ascertained from a table of tensions), and f'' the tension of vapour at the dew-point. Having thus found the value of f'', the temperature corresponding to it in a table of tensions is the dew-point,

$$\frac{\text{weight of cubic foot of vapour at the dew-point}}{\text{weight of cubic foot of vapour at dry-bulb temperature}} \times 100,$$

since the numerator is the weight actually present, and the denominator the weight which is required for complete saturation at the dry-bulb temperature.

In practice none of these calculations is necessary, since Glaisher's Tables give the relative humidity corresponding to all ordinary readings of the wet and dry bulb thermometers. This is by far the most important hygrometric datum, the absolute weight or tension of vapour present, and even the dew-point, being of minor interest. The relative humidity is an inverse measure of the drying effect of air. The capacity for taking up moisture increases with the temperature, but far more rapidly, so that the mere difference between the dew-point and the air temperature is no criterion of the humidity.

Aqueous vapour intercepts some of the sun's luminous rays, and very greatly impedes the radiation of non-luminous rays from the surface of the earth into space. Hence the difference between the sun-maximum and grass-minimum temperatures is chiefly dependent upon the humidity. The intensity of radiation at high altitudes is largely due to the absence of aqueous vapour.

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[*] Based upon the ‘Greenwich Factors,” or “Glaisher's Factors,” a different factor being employed for each temperature. If D is the factor corresponding to the dry bulb temperature, the dew-point is $t - D\,(t - t')$.

Humidity comes into question also in connexion with ventilation, the aim being to keep the air of rooms as near as practicable to the accepted *optimum*, namely, 70 per cent. of saturation. Hence in heating by convection it is desirable to moisten the air, and for certain trade processes in which air is steamed limits of relative humidity are imposed by law.

Evaporation from moist surfaces is affected by the temperature of the water, the temperature of the air, the humidity of the air, and the wind. It is more rapid from moist soil than from water; and deep-rooted crops, such as wheat, dry the soil to a greater depth than grass. No satisfactory instrument (*atmometer*) has been devised for measuring evaporation, owing to the difficulty of excluding rainfall while allowing free exposure. A rough estimate may be obtained by exposing a measured volume of water in an open dish of known area, and deducting from the final measurement the ascertained rainfall. The atmometer may be screened from rain by a cover, which necessarily lessens evaporation, or an index evaporation gauge (Negretti) may be used. Symons found that, at Lea Bridge, the mean annual evaporation per square inch of water-surface was 21 in., the rainfall being 25 in. In exceptionally dry years it exceeds the rainfall.

3. **Atmospheric pressure** is exerted equally in all directions at the same level (14 lb. to the sq. in. at sea-level), but on account of the compressibility of gaseous bodies the lower levels of a high column are denser than the higher. Air-pressure is measured by barometers. **Mercurial barometers** consist essentially of a glass tube some 33 in. long filled with mer-

cury, and then inverted over a mercurial trough. The tube being vertical, the mercury sinks until the column is of just sufficient height to balance the atmospheric pressure acting upon the free surface of the mercury in the trough. The vertical distance between the two mercurial surfaces exactly measures the pressure of the atmosphere in terms of mercury. The level of the top of the column is read off against a fixed scale, but as the level of the mercury in the cistern also changes slightly with every change of pressure, it is necessary to take this into account.

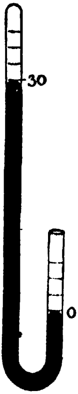

Fig. 5.—Siphon barometer.

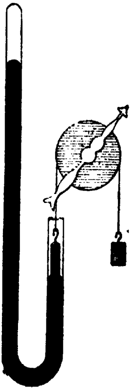

Fig. 6.—Wheel-barometer.

In Fortin's barometer the cistern has a leather bottom, which can be raised or lowered by means of a fine screw until the surface just touches a fixed ivory point. After this adjustment of the cistern to a constant standard level, the upper level is read upon a scale marked upon the casing of the tube.

In the Kew barometer the necessity for the adjustment is obviated by graduating the scale in nominal inches, which are shorter than true inches, and exactly correspond to the displacement caused by a change of pressure to the extent of 1 in. of mercury. A single reading therefore gives the true vertical height of the column.

In the siphon barometer (Fig. 5) the cistern is dispensed with, and the tube is of **U** shape, one arm being short and open at the end. Both levels are read upon a scale. The movement in either arm is little more than half that occurring in a cistern barometer.

The ordinary wheel-barometer (Fig. 6) is a siphon barometer, the movements being transmitted by a string from a float upon the mercury in the open tube to an axis which carries a long finger like that of a clock.

Greater accuracy in the reading is obtained by the use of the "vernier," a small movable scale which slides upon the principal scale (Fig. 7). If the barometer is graduated to $\frac{1}{20}$-in. divisions the vernier can be so graduated that 25 of its divisions correspond to 24 of those upon the other scale, and each division is therefore only $\frac{24}{25}$ of the length of the standard divisions. With sub-graduation the vernier will show differences of $\frac{1}{25}$ of $\frac{1}{20}$, i.e. 0·002, or $\frac{1}{500}$ in. When a reading is to be taken, the lowest mark on the vernier is accurately adjusted against the top of the mercurial column. If this level exactly corresponds with one of the divisions of the principal scale, the vernier correction is not needed; its lowest mark will coincide with the mark on the scale. If, however, the level of the mercury does not exactly coincide with a scale division, the vernier helps us to measure more accurately than is otherwise possible the fractional excess over the next division below. For this purpose we must follow the vernier scale upwards until we come to a mark upon it which corresponds more closely than any other to one on the fixed scale;

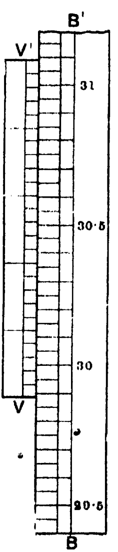

Fig. 7.—Barometer scale and vernier, showing a reading of 29·85 + 18×0·002 = 29·886 inches.

calling this the xth mark, the correct reading is 0·002 × x in. above the scale mark next below the mercury level. For example, the mercury stands above 29·85, but below 29·90, as read on the fixed scale, and upon inspection it is found that the sixth vernier division corresponds with a division of the fixed scale. This shows that the fractional excess above 29·85 is 6 × 0·002, or 0·012 in., and the true reading is therefore 29·862 in. Had the 20th division of the vernier been the one which coincided with a fixed scale mark, the fraction would have a greater value, 20 × 0·002 = 0·04 in., and the barometric reading would be 29·89 in. A little consideration will make it clear that as compared to scale divisions we lose 0·002 in. for every vernier division as we follow the marks upwards, until we have lost all the fractional excess over the 29·85 mark; and then the marks on the two scales will correspond.

The reading having been accurately taken with the aid of the vernier, it remains to apply certain corrections of error :—

(1) For "index error"—i.e. inaccuracies in the scale.

(2) For "capacity"—i.e. for the change in the cistern level, unless this is allowed for as already described. Practically, this correction is never called for in good modern barometers.

(3) For "capillarity," which tends to depress the column slightly.

These three corrections are special to each instrument, and Kew certificates give for each half-inch a correction comprising them all.

(4) For temperature, which affects the mercury, and also the brass or other scale. All readings are reduced to 32° F. by means of a table giving corrections for each temperature.

(5) For elevation. It is customary to reduce all readings to sea-level, i.e. the mean half-tide level at Liverpool. For this purpose it is necessary to know the exact height of the station and to refer to a table of corrections. Roughly speaking, the correction is about 1 in. for every 1,000 ft.

Owing to the high specific gravity of mercury, 13·5, a column of about 30 in. in height balances the atmospheric pressure, and there is the further advantage that the vapour-tension in the Torricellian vacuum above the mercurial column is trifling. The density of mercury, however, renders the range of movement under varying atmospheric pressures small, and other liquids have been employed in order to secure greater sensitiveness of indication. Jordan's **glycerin barometer** is the most important of these; glycerin has a specific gravity of 1·26, and a column of 27 ft. would about balance a mercurial column of 30 in. A fall of 1 in. of mercury is represented by a fall of 10·7 in. of glycerin, and the latter is therefore far more sensitive. **Water barometers** have also been constructed, a column of 34 ft. being required to balance 30 in. of mercury. These instruments are, of course, still more sensitive, and magnify the mercurial reading 13·5 times; but, in addition to the disadvantage of their height, the vapour tension in the vacuum is a source of error that varies with the temperature.

Aneroid barometers dispense entirely with liquids, and measure the barometric pressure by means of the elasticity of metal. A small air-tight metallic box is (nearly) exhausted of air, and is so constructed that the top is slightly forced in when the atmospheric pressure rises, and (aided by a strong spring) comes out when the pressure falls. These movements are conveyed by levers, etc., to a finger moving upon a dial; the dial is graduated empirically by comparison with a standard mercurial barometer.

There are periodic and non-periodic **variations of pressure** (due to temperature, vapour, land and sea, etc.), but the former are so masked by the latter in England as rarely to be perceptible except in averages. There is a tendency to a daily curve, with a range of about 0·02 in. There are two maxima, about 9–10 a.m. and 9–10 p.m.; and two minima, about 3–4 a.m. and 3–4 p.m. This slight curve is only noticeable in the rare absence of non-periodic changes; but in the Tropics the daily range exceeds

0·11 in., while in Arctic regions it vanishes. The annual curve in England is somewhat irregular, but has a maximum at the end of May, and a minimum at the end of October. It is very different in other countries.

Recording atmospheric-pressure variation.—If the readings of the barometer at any given moment at several stations dotted over a wide area, such as

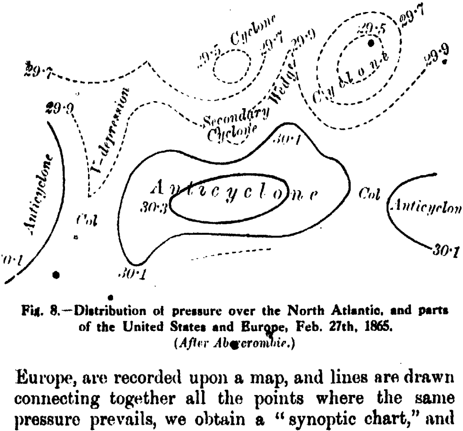

Fig. 8.—Distribution of pressure over the North Atlantic, and parts of the United States and Europe, Feb. 27th, 1865.
(*After Abercrombie.*)

Europe, are recorded upon a map, and lines are drawn connecting together all the points where the same pressure prevails, we obtain a "synoptic chart," and these lines, or *isobars*, are found to assume, very commonly, certain typical forms (Fig. 8).

(1) *Cyclones*, formed by concentric isobars, the lowest pressure being at the centre.

(2) *Anticyclones*, the isobars being roughly concentric, with the highest pressure at the centre.

(3) *Secondary cyclones*, formed by looped concen-

tric isobars (the circle being incomplete, and thus failing to form a true cyclone) with lowest pressure in the centre.

(4) V-*shaped depressions*, with lowest pressure in the interior, forming, for example, the angular intervals between adjoining anticyclones.

(5) *Wedges* of high pressure—highest in the interior—inserted between two adjacent cyclones, and usually pointing to the north.

(6) *Cols* or necks of comparatively low pressure between two adjacent anticyclones, like the pass or "col" between two Alpine peaks.

(7) *Straight isobars.*

Cyclones, secondary cyclones, V-depressions, and wedges, usually travel eastward at the rate of about twenty miles per hour, but anticyclones often remain stationary for days, weeks, or even months. If the direction of the wind at each station is marked upon the synoptic chart, it will invariably be found that it is roughly parallel to the isobars, and that in anticyclonic areas (in the northern hemisphere) it describes a circle in the same way as the hand of a watch, while in cyclonic areas this course is reversed.* The direction of the wind in these and in all other arrangements of isobars conforms to *Buys-Ballot's law*—that an observer standing with his back to the wind always has lower pressure to his left, and higher pressure to his right.

The closeness of the isobars, or, in other words, the rapidity of change of atmospheric pressure, forms the "barometric gradient," to which the velocity of the wind is directly proportionate.

4. **Atmospheric movements and wind.**—Inequalities of pressure and temperature are the two chief causes of atmospheric movements and of wind

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* The course of the wind is not exactly parallel to the isobars. The wind crosses the isobars obliquely, and may be described as blowing spirally into a cyclone and spirally out of an anticyclone.

(e.g. land and sea breezes), and, broadly speaking, control their direction. Not only the force and velocity of atmospheric movements can be inferred from the arrangement of the isobars, but also the kind of weather prevailing at each station. The front part of an advancing cyclone is associated with rain, stratiform clouds, and moist, heavy atmosphere, while in its rear the opposite conditions prevail, namely, sunshine, clear "fresh" air, and cumulus clouds. Anticyclones are less intense, more stationary, and cover a wider area than cyclones. In front of them and at the centre are found sunshine, blue sky, haze, little wind, keen dry air, and free radiation, with great daily range of temperature. The weather changes which accompany secondary cyclones or V-depressions are the same as those of cyclones; wedges, like anticyclones, have fine weather in front and bad weather in their rear.

All these types are liable to break up or merge into new forms at any time, but it is often possible to "forecast" the weather in any given locality by learning from the synoptic charts the direction and velocity of cyclones approaching from the west. Cyclones are often diverted from their course by meeting a coast line or mountain chain, or even an anticyclone; their course is not necessarily straight, nor their velocity by any means uniform. Lastly, their intensity—as measured by the steepness of the barometric gradient and consequent wind-velocity—may also change.

Cyclones are much more numerous than anticyclones. The centre of depression usually passes to the north of Britain, and hence it is more common for the wind to "veer" (or "go with the sun") than to "back." It is only necessary to imagine a watch (with its hand moving in the reversed direction) passing over a given point upon a map, to understand the successive changes in the direction of the wind at that point during the passage of a cyclone.

Wind may be measured, by *anemometers*, as regards either its pressure or its velocity.

Hooke's anemometer is a thin rectangular plate of iron, suspended from its upper edge, and set at right angles to the wind. The force of the wind is measured by the angular displacement of the plate. A pencil connected with the plate records upon a chart moved by clockwork the displacement.

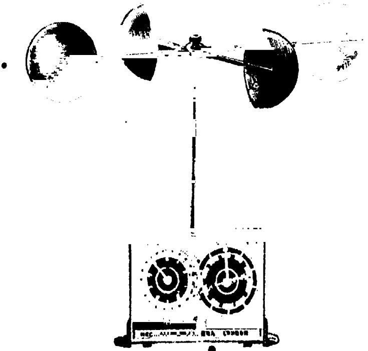


Fig. 9.- Robinson's anemometer.

In Osler's anemometer the principle is the same, but the weights are replaced by a spring.

Pressure anemometers (Dines) have the advantage of recording gusts and sudden changes in wind-pressure. So far as velocity and pressure are comparable, it may be said that the pressure varies as the square of the velocity. If V = the velocity in miles per hour, and P = the pressure in pounds per square foot, then, according to James,

$$V^2 = 200\,P.$$

Robinson's is the only one in common use. It consists of four light arms rotating in a horizontal plane around an axis, through which their movements are transmitted to a series of recording dials. Each arm has at its extremity a hemispherical cup, facing horizontally at right angles to the arm. In whatever direction the wind blows, the vanes revolve, the resultant pressure upon the concave surfaces being greater than that upon the convex. It was formerly believed that the cups moved with one-third the velocity of the wind, and the index dials were graduated accordingly. It appears, however, that the proportion is greater than one-third, and has a direct relation to the size of the cups and the velocity of the wind. Negretti now supplies a recording and an electric anemometer, by which Robinson's apparatus may be made self-recording (Fig. 9). Casella's air meter or pocket anemometer (Fig. 10) is used in mines, and for measuring the velocity of air-currents for ventilation purposes.

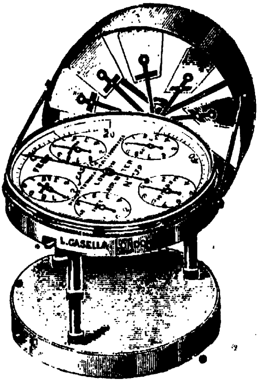


Fig. 10.—Pocket anemometer.

Apart from the uncertainty as to the true value of the readings of each instrument, the records of different stations are not strictly comparable, since inequalities in elevation and in shelter from the wind are inevitable, and must materially affect the results. The position of the anemometer should be such as to secure the fullest possible exposure to wind from all quarters.

The average velocity of wind in Great Britain shows a daily maximum and minimum closely corresponding to those of temperature, about 2 p.m. and 4 a.m. The annual curve of average wind-velocity has a maximum in July and a minimum in December or January.

In *Beaufort's scale* the force of the wind is stated by arbitrary numbers, ranging from 0 (calm) to 12 (hurricane).

Force.	Beaufort scale.	Miles per hour.
0	Calm	Up to 3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

In England the velocity is, upon an average, about 8 miles per hour, and rarely exceeds 40. Local winds may be caused by geographical configuration—e.g. sea coasts, high mountains, and other less well-defined factors. In normal conditions a wind blows at noon from sea to land, from plains to hills, but at sunset the directions are reversed. Winds increase in force with elevation. A "wind-rose" (Fig. 11) is a scheme showing the relative proportions of wind-observations from each point of the compass.

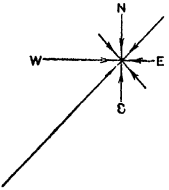
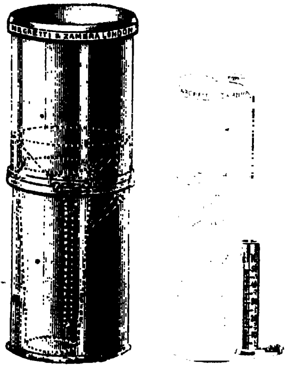


Fig. 11.—Wind-rose.

5. **Rainfall** is measured by a **rain-gauge** (Figs. 12, 13), consisting of a funnel leading to a bottle or other receiver. The funnel has a sharp, circular rim, usually 5 in. or 8 in. in diameter, and its area in square inches is accurately known. The water collected in the receiver is measured in a graduated glass vessel, the divisions of which correspond to the fractions of an inch of rainfall. It is found that the amount collected is greatest at the ground level. Care must be taken to place the rim of the gauge perfectly level and to select an open site. "No object ought to subtend a greater angle with the horizon than 20° in any direction from the gauge" (*Scott*). Snow and hail may be melted for measurement by adding a known volume of warm water, which must be deducted from the total. A recording rain-gauge, which registers on a chart both the rainfall and the time at which it occurred, is shown in Fig. 14.



Figs. 12, 13.—Rain-gauge.

As regards the daily curve of average rainfall there are indications of three maxima, the principal of which occurs about 2 or 3 p.m. The annual curve varies with locality. In London and on the east coast of England the principal maximum is in October, and the minimum in February or March; but on the west coast January is the wettest month.

The average annual rainfall varies from about 20 in. on the east coast of England to 60 or 80 in. on the west coast of Ireland and Scotland; and at Seathwaite, in Cumberland, it averaged 154 in. during six years. The average for England is about 25 in. The rainfall does not often exceed an inch in one day in Great Britain, but excessive quantities are recorded occasionally. It is greatest on the westward slope of English mountains, owing to the humid westerly winds depositing moisture as soon as they are forced to ascend into colder strata.

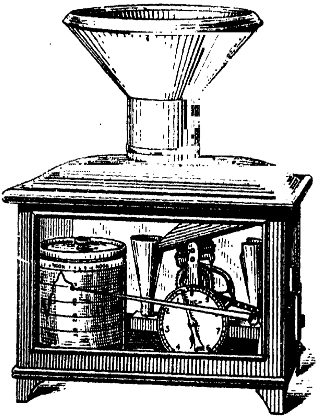


Fig. 14.—Recording rain-gauge.

The chart (left) shows 1 in. of rain for its entire depth; the pen begins its mark at the top of the chart and moves downwards as the rain falls. The chart is divided into $\frac{1}{100}$ parts, and the exact amount of rain and the exact time of its fall are recorded.

It must be remembered that rainfall by its condensation from vapour into liquid form gives out latent heat.

6. **Climate** is the condition of a country in relation to certain physical conditions and elements, viewed as to their effects upon animal or vegetable life. These conditions are (*a*) distance from the equator, or latitude; (*b*) relative distribution of land and water; (*c*) altitude; (*d*) presence of ocean currents; (*e*) rainfall; and (*f*) wind. Proximity of mountain ranges and their influence upon the shelter from wind and on the rainfall, soil and its permeability to moisture, and vegetation, also exert an influence on climate. The climate of the British Islands is typically marine, being greatly influenced by its insular position and the Gulf Stream, which latter causes the "isothermal lines" of the North Atlantic Ocean to run from S.W. to N.E. Such a climate is essentially a temperate one, free from extremes of heat and cold, and yet marked by a high degree of atmospheric moisture. Rheumatism, lung affections, and other diseases directly or indirectly due to such climates therefore abound. It is customary to divide climates into Warm (tropical and subtropical), Temperate, Cold, Marine, and Mountain climates, and in each of these disease bears some relation to the climate. Particularly is this true of tropical or subtropical climates, in which malaria, dysentery, liver abscess, cholera, yellow fever, and a variety of tropical parasitical diseases find favourable conditions. At the same time, much can be done by judicious living to enable the individual accustomed to one climate to live healthily in another.

CHAPTER III

WATER

Amount.—It is generally estimated that from 10 to 15 gallons of water per head per day are required for personal and domestic use, 5 to 10 gallons for municipal purposes and a similar quantity for trade processes, but all these items are liable to wide variation. About 20 to 30 gallons per head are supplied in most towns in Great Britain. The average daily amount taken in food is about half a gallon, but at least a pint of this is contained in solid food. Half a gallon more is used in cooking. Parkes suggested as a standard in a middle-class household 6 gallons per head for domestic washing, 5 for ablutions, including a sponge-bath, 6 for water-closets, 4 for general baths, and 3 for unavoidable waste.

Sources.—All natural waters are ultimately derived from the rainfall, which in its turn is due to distillation under the influence of the sun's rays from all humid portions of the earth's surface. Part of the rainfall is again evaporated from the surface upon which it falls; part flows over the uplands and forms rivers and lakes. A third part sinks into the soil, descending through fissures or pores, until it reaches an impervious formation, and it then either finds its way laterally to the surface in the form of springs, or accumulates in the porous strata overlying the impervious layer, where it may be reached from the surface by wells. It has been found that upon sand or gravel surfaces as much as 90 per cent. or more of the rainfall sinks into the ground, as compared with 40 per cent. on the chalk, and 20 per cent. on limestone, while upon clay scarcely any infiltration occurs. For obvious reasons the proportion is less in hilly districts, which offer greater facilities for surface-flow, and less in summer than in winter owing to excessive evaporation. The sources of water supply are therefore (1) upland surface rain-water, (2) wells and springs, and (3) river-water.

Rain-water is soft and well aerated, but its purity and fitness for drinking or even for washing depend upon the purity of the atmosphere through which it falls. Near the coast it often contains traces of chlorides and sulphates. In inland districts there is a marked increase in the sulphuric acid, ammonia, and organic matter, owing to putrefactive processes and the combustion of coal. Near towns rain may become acid in reaction, from excess of sulphurous and sulphuric acids, and is liable to carry down considerable quantities of tarry and carbonaceous matter from the smoky air. It acquires from the air not only oxygen, nitrogen, carbonic acid, and ammonia, with a minute amount of nitric acid, but also any organic or other impurities that may be present in the air. Ammonia is found in largest proportion during the early part of a shower. A litre of rain contains about 25 c.c. of gases, namely, 8 c.c. of oxygen, 16·5 c.c. of nitrogen, and 0·5 c.c. of carbonic acid. Dew and snow-water have practically the same characters as rain-water, except that the dissolved gases are in less amount in snow-water. The average of 20 years, less one-third, gives the amount of rain in the driest year, and plus one-third the amount in the wettest year. (*Hawksley.*)

Springs and wells.—The portion of the rainfall that sinks into the ground becomes heavily charged with carbonic acid from the air in the interstices of the soil, and aided by this and by the increasing pressure it dissolves out lime and various mineral salts from the strata through which it passes. From the superficial strata it also receives organic matter, but the tendency of filtration through the soil is to remove this, or (in the superficial layers, where oxygen is present) oxidize it with formation of nitrates. The nature and amount of the mineral matters in solution are determined by the soluble constituents of the various strata through which the water has passed, and the organic impurities are regulated by the facilities for pollution in the superficial soil and the completeness of purification by filtration. Hence the water in shallow wells, especially if situated near dwellings or manured lands, is liable to contain much organic matter washed from the soil, with or without partial oxidation into nitrates or nitrites; and also chlorides, which usually accompany organic impurities of sewage origin. In peaty districts the water acquires a brown tint due to vegetable matter.

According to the depth of the strata from which it is derived, the water may be warm, or of the mean temperature of the locality, or varying in temperature according to the season.

River-water is derived partly from springs, but chiefly from that portion of the rainfall which runs off the surface. Hence it contains a variety of mineral salts in solution, though in less amount than in spring or well water.

All streams are inevitably polluted to a certain extent by organic matter. Moorland streams contain peaty matter, sometimes in sufficient quantity to produce diarrhœa. Even in rural districts, the drainage from manured land and farmsteads finds its way to the river, and in times of heavy rain much impurity of animal and vegetable origin is washed into the watercourses. Such slight degrees of pollution are not regarded as rendering water unfit for drinking purposes, especially after filtration. Some of the organic matter is oxidized by agitation and aeration, assisted by nitrifying organisms, or removed by aquatic plants, and the bacterial contents of river-water may be much reduced by natural processes. For example, it has been shown by experimental investigation that the movement of river-water, and its pressure, exert such an influence. Oxidation, dilution, sedimentation, the bactericidal influence of light, and the antagonism of the fauna and flora of a river, also operate in the same way. When, however, the sewage of hamlets, villages, and towns is poured into the river, the pollution becomes more serious, and the self-purifying agencies are soon overpowered. There is no river in the United Kingdom long enough to effect the complete destruction of sewage by oxidation alone. Trade effluents—for example, refuse from dyeworks, paper-mills, and bleachworks—cause even more discoloration and turbidity than sewage proper. From these combined causes the rivers in the manufacturing districts become foul, discoloured, and offensive. Things are made worse by the refuse from slaughter-houses, solid household refuse, and even contents of privy middens being cast into the river. When the pollution reaches such a degree as this, the purification by oxidation is insignificant.

Owing to trade exigencies, volumes of water are in some places impounded, and are only passed into the stream during work hours. When water is abstracted from the head of a stream for the supply of a town, it is customary to provide a "compensation reservoir" in which the storm waters are impounded, and whence they can be delivered to supplement the remaining flow in the river in dry weather. As a means of regulating the flow these reservoirs are valuable; but as, for trade purposes, the discharge is often made intermittent, the lower part of the stream may suffer from delay in the delivery of the "compensation" water, in addition to the loss of the water permanently abstracted from the channel.

Mode of supply.—Thinly populated districts are dependent upon wells and springs, supplemented by rain-water collected and stored. Eighty per cent. of the water supply of London is still derived from the Thames and Lea, which are polluted rivers, the raw water of which needs filtration and storage (or treatment) before use. Many important cities derive their supply from natural lakes or artificial lakes made by impounding reservoirs (Glasgow, Edinburgh, Manchester, Liverpool, Birmingham, etc.).

Wells are of three kinds—(*a*) shallow or surface wells, (*b*) deep wells, (*c*) artesian wells. Shallow wells are those which are sunk in superficial beds of sand or other permeable soil, and which do not perforate through an impervious stratum. The depth to which it is necessary to sink a well depends upon the surface conditions as well as the arrangement of the strata beneath. Even "shallow wells" may yield good water unless exposed to pollution, as for instance by the proximity of leaking cesspools, ashpits, drains, or even dwellings. Water will usually be found, collected as in a basin, above the first impervious stratum of clay, and, as the surface of this subterranean reservoir will vary according to season, the well must be deep enough to reach its level in times of drought. Such a well drains a wide area, and is liable to be polluted by any impurity of the soil within a considerable radius of its mouth; and as the supply is at best subsoil water, due regard must be had to the possibility of pollution at comparatively distant points. It should be lined with brick and puddled, and the brick lining should be brought a foot or two above the ground so as to exclude

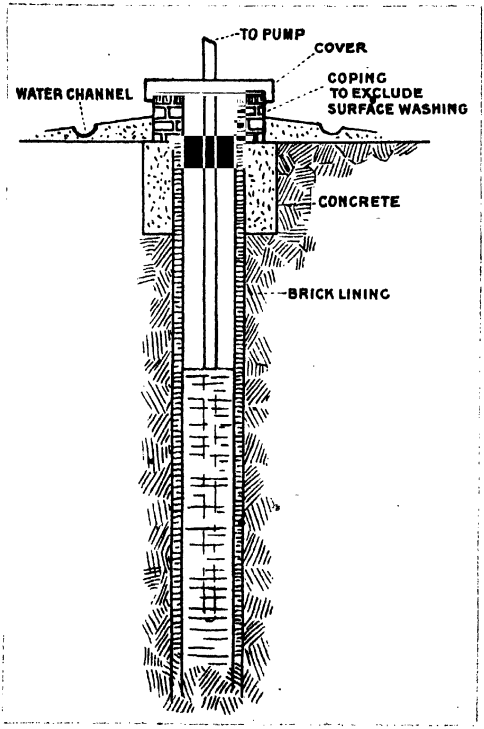


Fig. 15.—Method of protecting wells.

surface washings (Fig. 15). If the soil is polluted, or if the water found is impure or insufficient in quantity, the boring is carried through the first impervious stratum to other water-bearing strata deeper down, and such a well is known as a "deep well." Sometimes, in wells which perforate two impervious layers, the water in the deeper strata is under sufficient pressure to make it rise to the surface and overflow, forming an "artesian well" (from Artois, in France) or artificial spring. The flow in dense strata being slow, each well exhausts a considerable area, and the yield of water cannot be greatly increased by multiple borings. Borings in sandstone or limestone give large and constant supplies, owing to the enormous accumulations of water they contain, but wells in superficial sand or gravel beds, or chalk, often fail in dry seasons (Fig. 16). Artesian wells may be of great depth, 1,500–4,000 ft., and their water is high in temperature (80–180° F.). The water, though pure, is sometimes brackish. Many towns in England derive their water supply from artesian wells, which are also being much used in Australia.

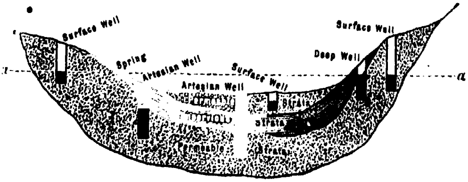


Fig. 16.—Diagrammatic section across a valley.
a a, Level of water in deeper permeable strata.

Wells derive their water supply from a wide *catchment area* or gathering ground. No habitations, farmyards, or sources of pollution should be permitted within the catchment area. The composition of water varies, of course, according to the soil of the gathering ground.

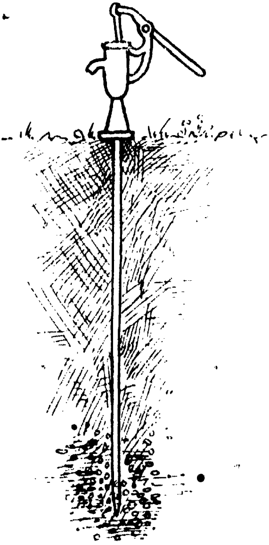


Fig. 17. Norton's tube well.

Tube wells ("Abyssinian") are convenient for small or temporary supplies. Norton's jointed iron tube (Fig. 17) is driven into the ground, section by section, the lowest bieng pointed and perforated at the end. When water is reached, it enters the tube through the perforations and is pumped up, if the pressure is insufficient to bring it to the surface. The average yield is about 7 gallons per minute from a depth of about 18 ft. If the yield is insufficient a Bastein pump may be used. Where the water does not rise to within 25 ft. of the surface a deep-well pump is necessary. "Abyssinian" tube wells are most suitable for gravel, coarse sands, chalk, and other porous water-bearing strata, and may be driven to any depth up to 150 ft. They are not to be recommended for clays, marls, and fine sands, and, of course, they cannot penetrate rock

There are two systems of boring wells, by *percussion* and by *drilling*, and various kinds of pumps are used for raising the water (air-lift, bore-hole, three-throw, hydraulic rams and water wheels, turbines and windmills).

In the country, and in certain towns where the air is free from smoke, the rain falling upon the roofs is collected and stored in cisterns for domestic use. It may, however, be collected from any other natural or artificial impervious surface. Its softness renders it valuable for washing, especially if the alternative supply is hard, but, owing to sooty and other matters acquired from the air and from the roofs themselves, it is seldom obtained in a state of sufficient purity for drinking purposes. It has been estimated that on the average only about two gallons per head *per diem* could be collected in this way.*

If rain is relied upon for more than an auxiliary supply, the collecting surface and storage capacity must be regulated by the minimum annual rainfall and the longest dry season.

Collection and storage.—Water is supplied to towns from reservoirs placed at a sufficient height to allow of its distribution by gravitation through open or closed aqueducts, leading to the street mains and through them to the service pipes. Pumping stations may be requisite in order to gain this elevation, and, if the source of water is of insufficient purity, settling tanks and filter beds may also be required. When the yield is liable to intermission, large storage capacity in the reservoirs becomes necessary. Supplementary service reservoirs, fed by the main reservoirs, are often constructed in elevated parts of the town, partly for convenience of distribution to certain districts, partly in order to supplement the supply during the hours of maximum demand, and so to avoid the necessity of regulating the calibre of the principal aqueduct by the greatest hourly consumption, which is double the average hourly consumption.

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* The annual yield is found by multiplying the inches of annual rainfall by the square inches of sectional area of the building (not the slant surface of the roof). This gives the cubic inches of water per annum, and, multiplied by 0·0036, the number of gallons.

If water with a head of H feet flows through L feet of pipe D inches in diameter, the discharge W in cubic feet per minute will be

$$W = 4{\cdot}72 \frac{\sqrt{H \times D^5}}{\sqrt{L}}. \quad \text{Hence } D = 0{\cdot}538 \sqrt[5]{\frac{L \times W^2}{H}}.$$

The source of supply may be deep wells, springs, lakes, rivers, smaller streams, or artificial adits from gathering grounds. Some of these sources are immediately dependent upon the rainfall for their continuance, so that in planning a water supply it is necessary to take into account (i.) the area of the gathering ground, (ii.) the minimum annual rainfall, (iii.) the longest rainless period, (iv.) the proportion of rainfall available for collection, (v.) the storage capacity of the reservoirs, and (vi.) the amount of water required by the district to be served.* Water of the greatest purity is obtained from deep wells, or from barren uplands, where the risks of animal or vegetable pollution are slight.

Impounding reservoirs are constructed either by excavation or embanking, the simplest plan being to carry an embankment across a valley. A lining of concrete or clay puddle may be needed to render them water-tight. The embankments, necessarily of great strength, have a core of clay puddle, and are protected from disintegration by a covering of grass on the outer side and dressed stone on the inner.

Means are provided of diverting the tributary streams along a by-wash when they become foul in flood times. The reservoir has an overflow weir, and can be emptied for cleansing purposes by means of a pipe, controlled by a sluice, leading from its lowest part. The most important points in the provision of reservoirs are—(*a*) suitability of site, (*b*) size, (*c*) sufficiency of water supply, (*d*) amount in gallons to be supplied per head per day, (*e*) the number of days' supply to be stored, and (*f*) the particular use to which the reservoir is to be put, namely, whether it is to be a quiescent settling basin or a continuous-flow settling basin, the latter being preferable.

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* In such cases the reservoirs should be large enough to hold at least 150 days' supply, and more in dry localities. If R = mean annual rainfall, E = evaporation (page 25), and A = acreage of gathering ground, then the mean daily yield in gallons is 62 A (R − E). In the driest year the rainfall will be one-half less, in the wettest one-half more, than the average. (*Symons*.)

From the reservoirs the water passes to the aqueducts by an outlet pipe, which is bent upwards at its commencement so as to take the purest water, free alike from sediment and floating matters. The aqueduct may be an open channel, but usually consists of iron pipes buried two or three feet in the ground as a protection against frost. The pipe aqueduct may be lined with pitch or other anti-corrosive, and, being water-tight, its course is not necessarily downwards at all points. Means of access are provided at short intervals for cleansing purposes; and if its course is undulating, sluices are needed at the lowest points for scouring out débris, and air vents at the summit.

Distribution.—Distributing conduits and mains convey the water to all parts of the district, and pass beneath the streets. They are similar in construction to the main aqueducts, and have "scouring valves" at all dead ends in order to wash out sediment. They should be kept as far as possible from the sewers and gas mains.* Hydrants are provided at short intervals for use in case of fire.

Service pipes convey water from the street main to the house, and are controlled by means of stop-cocks. Lead piping is generally used, owing to the many bends and joints needed in distributing water within the house. If, as is sometimes the case, the water is of such quality as to act upon lead, other materials must be employed for domestic supplies.

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* There is danger of in-suction if a perforation exists in a descending pipe, and especially at a point of constriction, even if the pipe is constantly full.

Constant and intermittent service.—In almost all provincial towns, and in most parts of London, the water supply is maintained constantly, save in times of exceptional drought. In some districts, however, the supply is only afforded for a certain number of hours in the day; and it becomes necessary for each household to store a sufficient supply for twenty-four hours, in elevated cisterns. The intermittent system, now becoming obsolete, is attended by many risks and disadvantages, and is only defended on the grounds that it incurs somewhat less waste, and that the substitution of constant service entails better fittings.

On the other hand, **house cisterns**, which must be large enough to meet the maximum (not the average) daily consumption, are costly, and are liable to become foul; the water stored in them is stagnant, and absorbs impurities from the air; coal-gas, sewer-gases, or liquid filth are liable to be drawn into the mains and service-pipes when empty; and, apart from this, the alternate contact with air and water tends to corrode the pipes and promotes the absorption of lead. In the event of fire, a house or district under the intermittent system is at great disadvantage. A cistern, if any is needed, should be placed at the top of the house, and fed by a supply-pipe controlled by a ball-cock. It must be large enough to contain at least a day's supply and must not directly supply the water closet. It may be made of lead, lined with pitch or other protective coating, or of galvanized or Barff iron, or of slate slabs set in cement. It should be effectually covered, but ventilated, and provided with an overflow (of greater diameter than the feed pipe) discharging into the open air away from any source of effluvia. Frequent inspection and cleansing are necessary.

Purification of water may be necessary on account either of excessive hardness, excess of saline constituents, suspended matters, organic matter in solution, or, lastly, on account of liability to specific pollution.

Distillation is widely applicable, and even sea-water can be utilized in this way. Distilled water has an unpleasant taste, and is said to be indigestible from its want of aeration. This can be remedied by exposure to the air in finely divided currents, as, for instance, by letting it fall from a sieve, or by charging it with CO_2 under pressure.

Boiling removes temporary hardness and destroys microbes, and therefore specific contagia. Some of the organic matter is carried down with the calcium carbonate. Boiled water tastes flat, and, like distilled water, needs aeration. Lime is thrown down more completely if sodium carbonate be added.

Chemical processes are for the most part intended to remove excess of lime. Hard water may be softened, and at the same time deprived of all suspended matter, organic or mineral, by adding about 6 grains of alum per gallon. Calcium sulphate and a bulky precipitate of aluminium hydrate are formed, and carry down suspended matters. If no calcium carbonate is present, calcium chloride and sodium carbonate must be added previously. Perchloride of iron (2½ gr. per gallon) acts similarly.

Clark's process.—Hard waters may be softened upon the large scale in reservoirs by adding to every 100,000 gallons of water 6 lb. of freshly burned lime for each degree of hardness. The lime and calcium bicarbonate react to form insoluble calcium carbonate, and this carries down with it suspended matters. A similar process may be employed on the domestic scale, using lime or washing-soda, or both. The *Porter-Clark process* is a modification of Clark's. Instead of waiting for a slow subsidence, which takes ten or twelve hours, the precipitated calcium carbonate is removed rapidly by filtration through cloth, under pressure.

In 1905 the Lincoln water supply (after the typhoid epidemic) was sterilized by means of *chloros* (an alkaline solution of hypochlorite containing 10–15 per cent. of available chlorine). In 1908 chloride of lime was used at Chicago, and at Aberdeen in 1915 a threefold scheme was adopted (excess lime treatment, storage for seven days, and filtration). The soft water of the Dee made it practicable to sterilize in 7 days with 1 lb. of CaO per 10,000 gallons of water. Hypochlorite sterilization of water (1 in 100,000) has been widely used in America in recent years with excellent results (*Houston*).

Filtration aims at straining off suspended matters, and oxidizing dissolved organic substances. Mineral salts in solution, such as sodic chloride or calcic sulphate, are at most only partially removed by filtration. As a rule, however, hardness is lessened, together with the nitrites and ammonia. Nitrates are increased.

For domestic filtration a sand filter capable of removing suspended matters and some of the organic impurity may be constructed like a miniature filter-bed, in an ordinary flower-pot, with or without the addition of a layer of animal charcoal (6–12 in. of fine, sharp sand, superimposed on an inch or two of small gravel). Sponge filters have deservedly fallen into disrepute; they remove suspended matters, but become foul and harbour organisms. Carbon is the commonest of all filtering media; and animal charcoal is believed to have a far greater purifying effect than vegetable charcoal. Many efficient patterns of filters are made essentially of animal charcoal; others depend upon silicated carbon, manganous carbon, magnetic carbide of iron, or "carferal" (charcoal, iron, and clay). Maignen's "Filtre Rapide" has no carbon block, but the water is made to pass through a mixture of powdered charcoal and lime (*carbo calcis*) supported upon an asbestos cloth; like other animal charcoal filters, it seems to have the power of removing lead; and the medium can be renewed without difficulty. Bischof's spongy-iron filter, besides removing the organic matter, lessens the hardness, and often reduces nitrates to ammonia. A filter may be attached to the water tap, as in Fig. 18.

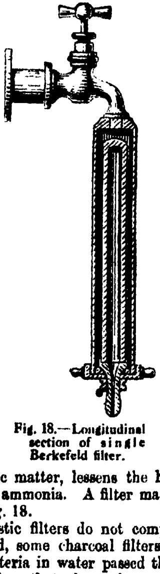

Fig. 18.—Longitudinal section of single Berkefeld filter.

Ordinary domestic filters do not completely remove microbes, and, indeed, some charcoal filters appear to increase the number of bacteria in water passed through them. This is owing to the fact that charcoal may add nitrogen and phosphates to water, which are both nutritive substances on which bacteria flourish, and may absorb impurities from the air, and thus favour the growth of organisms in its substance.

To remove all bacteria, filters of a different class are required, with excessively fine pores through which water can be forced under pressure, without permitting microbes to pass. Pasteur-Chamberland's, composed of porcelain formed by a mixture of kaolin and other clays, is the best example of this kind (*Woodhead*, *Horrocks*); the Berkefeld filter (Fig. 18), somewhat similar, is made of infusorial earth. If much organic pabulum be present in the water, or the filter be used intermittently, or the water forced through it, even filters of this kind are not proof against microbes growing through: and periodic sterilization by steam or boiling is therefore necessary.*

Sedimentation and filter-beds.—Purification of water on a large scale is now best secured by the double process of sedimentation by storage and filtration through sand.

Sedimentation takes place in large reservoirs before the water is passed on to the filter-bed. The action of gravity causes suspended matter to fall, carrying down with it micro-organisms. Aeration and sunlight play a part. Houston has pointed out that storage brings about not merely mechanical effects, but the absolute extinction of life of microbes. "Even a week's storage of raw river-water is an enormous protection, and less than a month's storage an apparently absolute protection, against the germs of typhoid fever." This applies equally to cholera. Raw river-water should therefore be stored *antecedently* to filtration, preferably for 30 days. Houston claims that storage reduces the number of bacteria of all sorts (often by 99 per cent.), alters the bacteriological ratio of water (by reducing *B. coli* to a proportionately greater extent than other water-bacteria), devitalizes the microbes of typhoid and cholera, reduces the amount of suspended matter, and has a marked

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* A filter (other than Bischof's) should be emptied from time to time to promote aeration, and requires frequent cleansing and occasional renewal of the carbon or other medium. Cleansing may be effected by scrubbing the carbon block, if removable, then running an acid solution of potassium permanganate through it, followed by copious washing with very weak hydrochloric acid and finally several gallons of water.

"levelling" effect on water delivered to filter-beds, thus prolonging the "life" of the beds. The use of stored water enables a *constant* check to be maintained on the safety of a water antecedently to, and irrespectively of, filtration. Storage thus acts by sedimentation, devitalization, and equalization. The only serious disadvantage of storage is the expense of constructing reservoirs and of management involved.

Filtration is usually necessary for the protection of a public water-supply. The "filter-beds" constructed for this purpose are essentially shallow reservoirs, 6 or 8 ft. deep, underdrained by perforated or loosely jointed pipes, to reach which the water passes downwards through successive layers of fine and coarse sand (2½ ft.), gravel (½ ft.), and broken stones and bricks (½ ft.), the total thickness being 3½-4 ft. Vents are carried from the deeper layers to above the surface of the water, to allow of the escape of the air displaced by the water as it first descends. From time to time the beds are run dry, for the purpose of aeration; and occasionally they are cleansed by scraping off the sediment and a little of the superficial fine sand, fresh sand being added when necessary. The suspended impurities are strained off by the upper portion of the filter, and a certain degree of oxidation of organic matter is effected by the aid of nitrifying organisms. Hardness is diminished somewhat, and iron is removed. It has been shown that filtration through sand removes 95 to 99 per cent. of the microbes present in water (80 per cent. of the bacteria removed were found in the upper inch of sand, and 55 per cent. in the upper quarter-inch). If the gelatinous film which forms at the surface of the filter is not disturbed, and if the speed of filtration does not exceed 4 in. per hour, practically all the microbes are arrested. Those in the effluent come from the filter itself, and should not exceed 100 per c.c. (*Koch*). Frankland holds that the *efficiency* *of sand filtration* depends upon (*a*) the storage capacity of the unfiltered water, for purposes of subsidence by sedimentation; (*b*) the thickness of fine sand through which the filtration is carried on; (*c*) rate of filtration; and (*d*) the renewal of the filter-bed. It is essential that the rate of filtration should be slow, about 1½ gallons per square foot per hour being the rule in the London waterworks, although in Paris it is as much as 3½ gallons, in Amsterdam 2½, and in Berlin 2. The gelatinous film on the surface of the filter is the "vital layer" where the process of nitrification and arrest of bacteria goes on, and it is there that the filter exerts its chief effect. It may therefore be said that sand filtration depends upon four processes: first, there is subsidence of the grosser particles of impurity in the settling tank; secondly, there is mechanical obstruction to impurities in the interstices of the filter; thirdly, there is oxidation of organic matter in the pores of the filter-bed; and fourthly, micro-organisms in the vital layer on the surface of the filter carry on the process of nitrification. The efficacy of the filtration can only be measured by periodical bacteriological and chemical examinations. The former should include an estimation of the number of bacteria present per c.c.

Other materials may be employed in the construction of filter-beds, such as magnetic carbide of iron covered by a layer of sand to intercept the suspended impurities. Such a filter-bed must be worked slowly and intermittently, so as to renew the aeration. Spongy iron can be used on the large scale, or "batteries" of Chamberland's filters. At Antwerp "revolving purifiers" are used—cylinders containing small loose pieces of spongy iron, and having many projections from the inner surface. Their long axis, upon which they rotate, is horizontal or inclined, and the surfaces of the iron masses inside are kept constantly bright and clean by mutual friction. Water is passed slowly through the cylinders as they revolve, and is exposed to the action of the constantly fresh iron surfaces. Subsequently sand filtration is used to remove the iron. Metal cylinders containing filtering material (known as "scrubbers"), polarite, sand and polarite mixed, etc., have also been used for filtration of water.

If the source of supply is a river, storm- or flood-water should be excluded. A preliminary purification by subsidence-tanks may be beneficial, and floating matters may be excluded by admitting the water from the river through a submerged sluice.

THE EXAMINATION OF WATER SUPPLIES

Collection of samples.—The amount required depends upon the mode of analysis to be adopted. Half a gallon, or $2\frac{1}{2}$ litres, will suffice for almost all purposes, and this quantity is held by an ordinary stoppered "Winchester quart." The bottle is rinsed out with a little hydrochloric acid, and then with water until the rinsings are no longer acid. At the time of collection it is again rinsed with sample water, and then filled up to the neck. The stopper should be tied in.

In order to obtain a fair sample, it is well, in the case of rivers or ponds, to plunge the mouth of the bottle under the surface of the water, at a distance from the margin, so as to exclude scum and débris, care being taken not to stir up any sediment. Tap water should be allowed to run for some time before sampling, unless it is desired to ascertain the maximum impurity.

Accompanying the sample should be a full and clear statement of its source. For, in addition to a chemical and bacteriological report of a water, there should also be made *a careful examination of the gathering ground.* The physical configuration of the gathering ground, its subsoil (the occurrence or otherwise of peat), its geology, its rainfall, its relation to the slopes which it drains, the nature of its surface, the course of its feeding streams, and the absence or presence of vegetation and cultivated areas, of roads, of houses, of farms, of human traffic, of cattle and sheep—all these points should be noted, and their influence, direct or indirect, upon the water carefully borne in mind.

When the sample has been duly collected, sealed, and a label affixed bearing the date, time, and conditions of collection, and full address, it should be transmitted (preferably in an ice-box) with the least possible delay to the laboratory, in order that the examination may be made immediately.

Physical characters.—Water should be clear and bright, free from turbidity or smell, and have a fresh, agreeable taste, without perceptible saline or other accessory character. The colour, as seen by looking down upon a white surface through a column of the water two feet in depth, should be clear, or slightly green, or blue; a yellow or brown tint raises suspicion of organic pollution. *Natural waters* may contain—*in suspension*, particles of animal, vegetable, and mineral origin; microbes, and other living organisms, animal and vegetable; *in solution*, gases, mineral salts, and soluble organic matter of animal and vegetable origin.

Suspended matters.—The water should be allowed to stand for a day in a tall glass, and the sediment then examined under the microscope.* Particles of sand have a sharp angular outline. Fragments of chalk and clay are amorphous, but a drop of acid introduced beneath the cover-glass will dissolve chalk, leaving clay unaffected. Shreds of cotton or linen are easily recognized under the microscope, and so are fragments of leaves, woody fibre, and other vegetable tissues, if not so decomposed as to be apparently structureless. Hair, wool, fragments of insects, and even epithelial scales may be found; brown globular bodies attributed to sewage contamination are sometimes seen in polluted water.

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* One form of sediment tube is shaped like a pipette, the point of which fits accurately into a little glass cup wherein the sediment collects. Finally a long rod is passed down the tube so as to stopper it from the inside at the point. The cup, containing the sediment and about 1 c.c. of water, can then be removed for examination

For the most part suspended matters can scarcely be deemed injurious; but some of them, cotton fibres for example, may supply important evidence of pollution by household waste, or even sewage.

Living organisms.—Rhizopoda, Infusoria, Hydrozoa, Rotifera, Scolecida, Entomostraca, and Insecta are found in water, together with Fungi, Algæ, Diatomaceæ, and many other organisms. For the most part these are believed to be harmless in themselves, though Infusoria (e.g. *Paramecium*, *Vorticella*) and Fungi indicate the presence of impurities, and a relatively large number or amount of vegetable or animal forms of life indicates the presence of organic pabulum for their sustenance. Among the parasites that are believed to be conveyed by water are certain tapeworms, the guinea-worm, *Dochmius duodenalis*, *Bilharzia*, and leeches. They may be found in the adult or embryonic form, or as ova.

Bacteria in water.—In all surface waters bacteria abound, and they are often present in small numbers in deep-well or spring waters. Water bacteria include micrococci, spirilla, and bacilli, the last being by far the most common group. They multiply in water with great rapidity. If a sample of ordinary water be allowed to stand, it will be found that in 24 hours there has been enormous multiplication, which continues for three or four days, until there may be hundreds of thousands or perhaps millions of bacteria in a cubic centimetre; then, the pabulum and volume of water remaining the same, there will be a diminution, until in, say, two or three months' time there will be, in all probability, few or none. In a general way it may be said that foul waters rich in putrescible animal matter show a very rapid increase of bacteria; surface waters, such as river water, show a slow and persistent multiplication of organisms; whereas deep-well waters and spring water show comparatively little increase in contained bacteria. The three chief conditions affecting multiplication of bacteria, with few exceptions, are (*a*) temperature, (*b*) period of time of standing, and (*c*) pabulum in the water.

Number of bacteria in water.—Deep-well water generally contains but few bacteria (say 1–10) per c.c. River water varies in its bacterial content according to season (i.e. temperature) and according to degree of pollution of the river (i.e. organic pabulum). For the period 1908–16 the *raw* Thames water contained 440 microbes per 10 c.c. (bile-salt agar test), whereas *stored* Thames water contained 50 per 10 c.c. (*Houston*). Prausnitz showed long ago that waters differ in bacterial content, as would be expected, according to the locality in the river at which examination is made. His investigations were made from the Isar before and after it receives the drainage of Munich, with the following results:—

Above Munich	531	bacteria	per c.c.
Near the entrance of principal sewer ..	227,369	,,	,,
Thirteen kilometres below Munich ..	9,111	,,	,,
Twenty-two ,, ,, ..	4,796	,,	,,
Thirty-three ,, ,, ..	2,378	,,	,,

In this country many similar investigations have been made. In 1901 Boyce found in the Severn:

Two miles above Shrewsbury	7,000	bacteria	per c.c.,	including	18	B. coli.
Opposite Shrewsbury ..	13,000	,,	,,	,,	46	,,
One mile and a half lower down	23,000	,,	,,	,,	321	,,
Two miles and a half ,,	19,000	,,	,,	,,	600	,,
Nine miles ,,	13,000	,,	,,	,,	48	,,
Sixteen miles ,,	5,000	,,	,,	,,	36	,,

From these and many similar records it is evident that, in the result, the number of bacteria in river water depends upon a variety of circumstances, amongst which the most important direct conditions are (1) local pollution; (2) natural purification; (3) season and rainfall; (4) sedimentation and filtration. Behind these direct conditions we also know that time, temperature, sunlight, exposure to air, etc., exert more or less influence.

There is no hard-and-fast rule as to how many bacteria a potable water should contain, as the kind of bacteria and the relative abundance of each species are more important data than actual numbers. Koch, however, has suggested 100 bacteria per c.c. as a maximum number for a properly filtered water. Macé proposed a standard of 0–50 per c.c. as "very pure," and 50–500 per c.c. as "good water." Estimations of water based only upon counting "colonies" of bacteria in plate cultures are of little value, but, other things being equal and constant, a small number of organisms tends to indicate a small degree of organic pollution and conditions unfavourable to the multiplication of bacteria. Broadly, it is true that a water containing a large degree of organic matter, the pabulum of bacteria, will contain a higher number of bacteria than a water containing a low degree, and this, of course, is the scientific reason for quantitative estimations.

Species of bacteria in water.—There are three chief groups of water bacteria, as follows:—

1. *Ordinary water bacteria*, including the fluorescent bacilli, liquefying and non-liquefying, many of the common chromogenic organisms, and organisms of air and soil. They are of little importance unless present in large numbers, and they possess no pathogenic power.

2. *Sewage bacteria*, including *B. coli communis* and its allies, the *Proteus* family, *B. enteritidis sporogenes*, and certain streptococci and staphylococci. The most important member of this group is *B. coli*.

The important points concerning *B. coli* are its differential diagnosis from the typhoid bacillus and its value as an organism of "indication" of fæcal pollution. The following characters are now commonly relied upon: 1. The *B. coli* group is non-sporing and non-liquefying. 2. The members of the group rarely stain by Gram's method. 3. They produce acid and gas with both glucose and lactose. 4. They produce acid in milk, and they usually also coagulate it. 5. They produce acid and gas in bile-salt-glucose broth. 6. They grow well at a temperature of 21° C. Other fairly reliable features are motility, a small number of flagella, a fairly typical growth on potato, and more rapid development on all media than the typhoid bacillus. In examining the London water-supply Houston uses what he describes as presumptive, confirmatory, and typical tests for *B. coli*. The *presumptive* test is gaseous fermentation of a bile-salt-glucose peptone medium; the *confirmatory* test is the isolation of a coli-like microbe forming gas either in a lactose or glucose medium; and the *typical* test is the isolation of a coli-like microbe forming indol in peptone-water cultures and gas in a lactose medium (the "flaginac" reaction). It is also desirable to remember the characteristics of the three groups of bacilli most readily confused with the coli group. These with their characteristics are as follows: (*a*) The *Proteus* group, the members of which are motile, liquefy gelatin, produce gas in glucose and saccharose but not in lactose, curdle and acidulate milk very slowly, and usually produce indol; (*b*) the group including *B. lactis aerogenes*, non-motile bacilli, which do not liquefy gelatin but which curdle and acidulate milk and ferment sugars other than glucose; and (*c*) the *enteritidis* group, containing bacilli which are motile, which only ferment glucose, and which do not liquefy gelatin or curdle milk, which is ultimately rendered alkaline. This group includes *B. enteritidis* of Gaertner, the paracolon and the paratyphoid bacilli.

Streptococci in water usually denote recent and dangerous pollution of water with sewage matter. They are absent from even large quantities of pure water and from virgin soils.

3. *Pathogenic bacteria.*—The two chief types are the typhoid bacillus and the cholera bacillus. As a rule pathogenic germs occur in water scantily and intermittently. They gain access at the source or

gathering ground, in the course or from drainage and sewers, or, thirdly, in the home of the consumer.

Bacteriological examination of water. — Strict cleanliness must be observed in collecting samples for bacterioscopic examination. Only sterilized vessels or flasks must be used (by heating to 150° C. for 2-3 hours), and great care must be taken in manipulation at time of collecting the sample in order to avoid the smallest degree of external pollution. The object of bacteriological examination of water is fourfold. (*a*) The average number of microbes per c.c. on a medium incubated at room temperature (20–22° C.); (*b*) search for *B. coli* and its identification in 0·1, 1·0, and 10 c.c.; (*c*) enumeration of bacteria capable of growing at blood-heat (36–38° C.); (*d*) search for and determination of special microbes. Small quantities of the water to be examined (0·1, 0·2, or 0·3 c.c.) are added to tubes of sterile liquefied gelatin, which are then poured into sterilized Petri dishes. The gelatin solidifies, and the plates are incubated at 20-22° C., and examined day by day. Soon after the lapse of 24 hours, colonies, arising from original individual bacteria, appear. These are examined by naked eye and microscope, and subcultures made in test-tubes containing suitable media—gelatin, broth, milk, agar, bile and sugar media, etc. Thus the number of organisms per c.c. can be estimated, and the species isolated and separately studied in "pure culture" under favourable conditions. Culture plates should also be made for incubation at blood-heat. Slide preparations, stained or unstained, should be made for microscopical examination. Special media and tests abound: peptone water for cholera red reaction, bile-salt agar (lactose and saccharose), liquid peptone sugars, litmus milk at 37° C., etc.

Some bacteriologists prefer to take a sterilized Berkefeld filter and pump or aspirate through it 1,000-2,000 c.c. of the water under examination, and with a sterilized brush transfer the particulate matter which has collected on the candle of the filter into 10 c.c. of water or broth. This is now a concentration or emulsion of the organismal content of the water, and may be plated out as above or examined for special organisms (*B. enteritidis sporogenes*, *B. coli*, *B. typhosus*, streptococci, or sewage organisms).

Other bacteriologists, aiming mainly at the detection of organisms of intestinal type, examine for (*a*) average number of microbes per c.c. on gelatin at 20-22° C. on third day; (*b*) *B. enteritidis sporogenes* in 0·1, 1·0, and 10 c.c. respectively; and (*c*) *B. coli* in 0·01, 0·1, 1·0, 10, and 100 c.c. respectively.

B. coli may be tested for as follows: Inoculate bile-salt-glucose peptone with 0·1–100 c.c. of water; after forty-eight hours' incubation at blood-heat the presence of gas necessitates secondary cultures to determine (*a*) fermentation of glucose or lactose or both; (*b*) the production or not of acid; (*c*) indol in peptone water; and (*d*) negative result in saccharose (cane sugar).

Gases in water.—A litre of water can dissolve 25 c.c. of oxygen, 46 c.c. of nitrogen, and 1,000 c.c. of carbonic acid at ordinary temperature and pressure. These gases are usually present in natural waters, but the proportions are very variable, being largely dependent upon the source of the water, the degree of pollution and of exposure to air, and also upon vegetable growth; chalk and limestone waters contain excess of carbonic acid. The gases in a pure water often contain 30 per cent. of their volume of oxygen. They may be extracted for the purpose of quantitative analysis by means of a Sprengel pump, or by boiling the water for an hour, and collecting over a mercurial trough. Potash will then absorb the carbonic acid, and potassium pyrogallate or sodium hyposulphite will remove the oxygen, leaving a residue of nitrogen alone.

For the determination of oxygen alone, Thresh adds measured quantities of sulphuric acid, sodic nitrite, and potassic iodide to a measured volume of water (about 250 c.c.), in a vessel which must be full to the stopper so as to exclude atmospheric oxygen. The nitrous acid acts as a "carrier" until all the dissolved oxygen is exhausted, liberating a proportionate amount of iodine. The water is then run into a bottle through which a current of coal-gas is being passed, and standard hyposulphite is added from a burette until the yellow colour due to iodine disappears, the final point being accurately determined by adding a little starch, which gives a blue colour as long as any trace of free iodine remains. The hyposulphite solution is of such strength (7·75 grm. per litre) that 1 c.c. corresponds to ¼ mg. of oxygen. A correction is required for the oxygen contained in the reagents used, a blank test being made for the purpose. The amount of dissolved oxygen per litre of water is then readily calculated.

Sulphuretted hydrogen or marsh gas may be found, the former due to mineral sulphides such as pyrites, or to decomposition of sulphates by organic matter, the latter to fermentation of vegetable matter in stagnant pools, or to pollution by coal-gas. Traces of ammonia are usually present.

Well aerated waters are bright, lustrous, and agreeable to the palate. This is especially the case with water from wells or springs, of medium depth, in calcium carbonate formations—the low temperature and greater pressure combining to increase the charge of carbonic acid. The absence of dissolved gases in distilled water renders it flat, dull, and unpleasant to taste.

MINERAL SALTS

Mineral salts are derived from the strata with which the water has been in contact, or otherwise. They may include chlorides, sulphates, carbonates, silicates, nitrates, nitrites, and phosphates, the bases being lime, magnesia, soda, potash, alumina, or iron, and more rarely lead, zinc, copper, manganese, or arsenic.

The proportion of salts present ranges from practically nil in rain-water, or pure moorland water, to 300, or more, parts per 100,000 in "mineral" waters or brackish water from the coast. In water for drinking it should not exceed 60 parts per 100,000, and a good water will not contain more than about 40 parts. An excess of mineral salts in general leads to digestive disturbances, in the form of dyspepsia, diarrhœa, or constipation; but this effect is largely dependent upon the nature of the salts present.

Chlorides, estimated as chlorine, may reach the proportion of 10 parts per 100,000 in organically pure water from the New Red Sandstone, Greensand, and other saliferous formations. Brackish water and sea-water contain excess of chlorine. In general, however, good waters contain not more than about 2 or 3 parts per 100,000, and rain-water and peaty waters little or none. Water from surfaces, shallow wells, or other sources open to contamination should be regarded with suspicion if it contains more than 10 parts of chlorine, especially if there is also excess of ammonia, organic matter, or oxidized nitrogen, all these being significant of sewage or animal pollution.

TESTS. 1. *Qualitative.*—A solution of silver nitrate gives a turbidity or a precipitate according to the amount of chlorine present.

2. *Quantitative.*—A standard solution of silver nitrate is employed, containing 4·588 grm. per litre, so that each c.c. corresponds to 1 mg. of chlorine, according to the equation $AgNO_3 + NaCl = NaNO_3 + AgCl$. A hundred c.c. of sample water are taken in a white porcelain dish, a few drops of a solution of potassium chromate are added as an "indicator," and the silver solution is then dropped in from a burette, with constant stirring, until a faint permanent red tinge appears, showing that the chlorine is exhausted, and silver *chromate* is beginning to be formed in place of *chloride*. If the 100 c.c. of sample water take x c.c. of silver solution before the red tint appears, there are x mg. of chlorine in the 100 c.c., and, therefore, $x \times 10$ mg. per litre.[*]

Sulphates are usually estimated as sulphuric anhydride, SO_3. The most important are calcium and magnesium sulphate, which are liable to cause dyspepsia and diarrhœa in persons unaccustomed to the use of water containing these salts. Hence limestone and dolomite waters, which may hold 5 to 20 parts per 100,000 of calcium sulphate, are less wholesome than chalk water, which contains none. Dolomite water differs from limestone water in containing magnesium sulphate, but less calcium sulphate. Some waters contain sodium sulphate. The acidity of certain peaty moorland waters that act upon lead has been attributed to the formation of acid sulphates by the oxidation of sulphides (pyrites) or of sulphurous acid absorbed from smoky air.

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[*] 1 mg. per litre = 0·1 part per 100,000, and 1 gr. per gallon = 1 part per 70,000. Hence x gr. per gallon = $\frac{100}{7}$ x mg. per litre, and y mg. per litre = $\frac{7}{100}$ y gr. per gallon.

TESTS. 1. *Qualitative.*—A solution of barium chloride, with a few drops of hydrochloric acid, will give a white precipitate.

2. *Quantitative.*—200 c.c. of sample water are boiled, treated with a little hydrochloric acid and slight excess of barium chloride solution, and then boiled again and filtered. The precipitate collected on the filter is washed, ignited, and weighed as barium sulphate, $BaSO_4$. Given the weight of $BaSO_4$ from 200 c.c., the corresponding proportion of SO_3 per litre will be readily calculated.

Carbonates.—Soluble calcium bicarbonate, $CaH_2(CO_3)_2$, is found in almost all well and spring waters. It occurs in excess in chalk, limestone, and dolomite water, but it is wanting in rain and peaty water. It is precipitated by boiling, in the form of normal calcium carbonate, $CaCO_3$. Magnesium bicarbonate, $MgH_2(CO_3)_2$, found in dolomite water, behaves similarly, but partially redissolves on cooling. Sodium carbonate, Na_2CO_3, may be found in natural waters, and may give them an alkaline reaction. Free carbonic acid exists in all waters, and if in excess renders them sparkling and palatable. Apart from this, the importance of the carbonates in water depends entirely upon the bases they contain. The determination of temporary hardness will show the amount of calcium and magnesium carbonates.

Silicates of soda or alumina are occasionally found in water.

TEST.—Half a litre of sample water is evaporated to dryness; the residue is acted upon by strong hydrochloric acid, and washed with boiling distilled water; then it is once more dried, ignited, treated with acid, and washed with boiling water. The final residue is silica, and may be weighed as such after drying.

Nitrates and nitrites, like chlorides, are harmless in themselves, but if found in a water exposed to risk of pollution may suffice to condemn it for use. Nitrates may be found in pure water from deep wells in the chalk, but as a rule they are due to oxidation of nitrogenous organic matter of animal origin. Even if accompanied by only a small proportion of organic matter, nitrates in water from a source open to suspicion must be regarded as oxidized filth, which may at any time be followed by unoxidized filth.

Frankland emphasized this view by recording all the inorganic nitrogen present, whether in the form of nitrates or nitrites, or ammonia, as due to *previous sewage contamination*, irrespective of its probable origin, recent or remote. He makes a deduction, however, of 0·032 part per 100,000, as the average amount of nitrogen in the rain-water which must have been the ultimate source of supply.

An example will make the mode of calculation clear. A sample of water is found to contain 3·1322 parts of oxidized nitrogen (i.e. nitrogen as nitrites and nitrates) per 100,000 parts of the water; and also 0·0034 part of ammonia, which is obviously equivalent to 0·0028 part nitrogen. The "inorganic nitrogen" is therefore 3·1322 + 0·0028, or 3·1350 parts per 100,000. From this must be deducted 0·032, as a correction for the nitrogen in average rain-water, leaving 3·1030 inorganic nitrogen, and this multiplied by 10,000 gives 31,030 (per 100,000) of "previous sewage contamination." In other words, if 31,030 parts of average London sewage had been diluted with 68,970 parts of average rain-water, and all the nitrogen then converted into nitrates, nitrites, or ammonia, the result would be a water of the composition of the sample so far as the proportion of inorganic nitrogen is concerned.

The process of nitrification, by which nitrogenous organic matter in water or in the soil is oxidized, with formation of nitrates, is due in great measure to the action of microbes.

Nitrites, as a rule, indicate more recent and therefore more dangerous pollution than can be inferred from the presence of nitrates. They readily pass into nitrates. A high oxidized-nitrogen figure, combined with excess of free ammonia, organic ammonia, and "oxygen absorbed," shows that the oxidation and destruction of organic matter are incomplete, and therefore dangerous.

A variety of standard terms has been proposed for the quantitative statements of nitrates and nitrites. The expression "oxidized nitrogen" is adopted here, and is equivalent to "nitrogen as nitrates and nitrites" and to "nitric nitrogen." "Previous sewage contamination" has already been explained. Wanklyn gives his results in terms of "nitric acid," HNO_3.

Water from springs and deep wells contains upon an average about 5 parts of oxidized nitrogen per million, shallow-well waters from 2 to 200 parts.

TESTS FOR OXIDIZED NITROGEN *

1. QUALITATIVE.

α. *Diphenylamine test.*—A 2-per-cent. solution of diphenylamine in strong sulphuric acid is spread out in a thin layer upon a white porcelain plate. A drop of the sample water is allowed to fall in the centre, and any trace of oxidized nitrogen is revealed in a few seconds by a blue tint throughout, or at the line of contact.

β. *Horsley's test.*—Two c.c. of pure sulphuric acid are added to 1 c.c. of the water, and then a drop of pyrogallic acid solution. A pink or blue tint appears, changing to brown; it disappears momentarily upon shaking, but soon returns.

γ. *Brucine test.*—A drop of pure sulphuric acid and a crystal of brucine added to the dry residue of 2 c.c. (or more) of the water will give a pink or yellow tint even with minute traces of oxidized nitrogen.

2. QUANTITATIVE.

δ. *Aluminium process.*—Two grm. of sodium are dissolved in 100 c.c. distilled water so as to obtain a pure solution of caustic soda free from nitrates; 100 c.c. of sample water and a piece of aluminium foil are added.

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* That is, for nitrates or nitrites indifferently.

In the course of a few hours all the oxidized nitrogen is converted into ammonia, which is distilled off and Nesslerized. Each mg. of ammonia, after deducting the free ammonia originally present in the sample, corresponds to 0·82 mg. of oxidized nitrogen in the 100 c.c. of sample.

Zinc-copper process.—Zinc foil is coated with copper by exposure to a solution of copper sulphate until it becomes black. It is then put into a bottle with 250 c.c. of the sample water and 0·5 grm. oxalic acid, and left for twenty-four hours. As in the aluminium process, all the oxidized nitrogen is converted into ammonia and measured as such by Nesslerizing.

All the preceding tests are for nitrates and nitrites alike. The following apply to nitrites only:

(1) Ilosvay's solution, containing sulphanilic and acetic acids and naphthylamine, is an extremely delicate test. A few drops added to water give a rose tint if any trace of nitrate is present.

(2) One drop each of phenol and sulphanilic acid solution, and then ammonia, will give a yellow colour.

(3) The addition of starch solution, potassium iodide solution, and dilute sulphuric acid causes a blue tint, due to liberation of iodine by nitrous acid and consequent formation of iodide of starch.

(4) Meta-phenylene-diamine solution with dilute sulphuric acid (1 c.c. of each to 100 c.c. of water) will give an orange-red colour after standing a few minutes. (*Griess.*)

Phosphates are not of common occurrence except in minute traces. They are, for the most part, indicative of remote animal pollution, but their presence need not condemn a water if other indications are satisfactory.

TEST.—The water is concentrated to $\frac{1}{50}$, 250 c.c. being boiled down to 5 c.c. Nitric acid is added, and then solution of ammonium molybdate. If phosphates are present, a yellow colour will appear, and, on standing, a precipitate of ammonium phospho-molybdate.

Sulphides are said to result from the reduction of sulphates by *Beggiatoa*, and perhaps from contact with iron pyrites. Carbonic acid liberates sulphuretted hydrogen from sulphides. They are readily detected by smell, and by the following: —

TESTS.—A solution of lead acetate (or, still better, a solution of lead hydrate in caustic soda) will give a black precipitate in presence of sulphides.

A solution of sodium nitro-prusside will give a purple colour with sulphides, but not with free sulphuretted hydrogen. It is therefore safer first to add caustic alkali.

Lime is the most important of the mineral constituents of drinking water. It occurs mainly as bicarbonate and sulphate; a good water should not, as a rule, contain more than 20 parts per 100,000 of the former, or 5 of the latter. In excess it causes constipation when used for drinking, and is wasteful for washing purposes, since it renders the water extremely hard unless previously boiled. On the other hand, absence of lime salts is held to be disadvantageous, because lime is required in the system, and also for the more practical reason that soft waters are, as a rule, less palatable than those of moderate hardness, and often dissolve lead from household service pipes. Horses are said to become rough in the coat if supplied with very hard water. Calcium sulphate is injurious (as already stated), and renders water permanently hard. Calcium nitrate and butyrate have been found in waters that have caused diarrhœa and other symptoms of intestinal irritation.

TEST.—Ammonium oxalate solution will give a turbidity or a precipitate according to the amount of lime added. This precipitate from a measured quantity of sample may be collected on a filter, washed, dried, ignited, and then weighed as calcium oxide.

Magnesia occurs chiefly as carbonate and sulphate, in water derived from magnesian limestone. It renders water hard, and, although the carbonate is thrown down by boiling, it redissolves on standing. Magnesium salts cause dyspepsia and diarrhœa.

TESTS.—All the lime is first removed by adding powdered oxalate of ammonia, and filtering.

(*a*) The filtrate is tested for hardness in the usual way. Any hardness beyond that of pure water is due to magnesia, and each "degree" corresponds to 0·56 gr. of magnesium carbonate per gallon.

(*b*) To the filtrate are added sodium phosphate, ammonium chloride, and excess of pure ammonia. In 24 hours the precipitate of triple phosphate, NH_4MgPO_4, is collected, washed on a filter with strong ammonia,* ignited, and weighed as magnesium pyrophosphate $(MgO)_2P_2O_5$.

Soda salts are almost omnipresent, and few waters are free from sodium chloride in small amount. The sulphate occurs in excess in some mineral waters, and the carbonate also is common, sometimes in sufficient quantity to render the water alkaline.

Iron is an occasional ingredient in natural waters, to which it gives a characteristic inky (chalybeate) taste. It is also frequently derived from iron tanks or pipes through which the water has passed. Water is unsuitable for drinking if it contains more than 1 gr. of iron per gallon—that is, 1·5 parts per 100,000. Ferruginous waters are said to be liable to cause dyspepsia, headache, and malaise in those unaccustomed to their use. Iron adds to the hardness of water.

TESTS. 1. *Qualitative.*—Ammonium sulphide gives a dark colour (lost on adding acid), potassium ferrocyanide a *blue*, and potassium sulphocyanide (after acidulating with nitric acid) a *red* tint.

2. *Quantitative.*—A standard solution containing 1 mg. of iron in 1 c.c. is made by dissolving 4·96 grm. of crystallized ferrous sulphate in a litre of water; if greater precision is desired, the solution may be diluted to $\frac{1}{10}$, so that 1 c.c. = $\frac{1}{10}$ mg. of iron. Of sample water 50 c.c. and of distilled water 50 c.c. are placed in Nessler glasses (p. 81) side by side, and

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* Triple phosphate is soluble in water. It is necessary to allow 1 mg. of magnesium phosphate as lost for every 50 c.c. of wash.

to both a trace of ammonium sulphide is added. The black tint produced in the former is exactly matched in the latter by adding successive c.c. of iron solution until the right shade is reached. The amount added (to the 50 c.c.) being known, the proportion per litre (i.e. per 1,000 c.c.) will be just twenty-fold, and will give, of course, the milligrammes per litre, or parts per million, of iron in the sample water.

Lead, rarely present in natural waters, is sometimes absorbed from leaden pipes or cisterns. The action is probably twofold. First, the metal is acted upon by the oxygen dissolved in the water, aided possibly by oxidized nitrogen serving as a "carrier" of oxygen. Next, the lead oxide thus formed may be dissolved, more readily, of course, if the water be acid, or may be washed away by the current in a state of fine powder. If, however, the water contains calcium carbonate, there is formed on the surface of the lead a protective coating, insoluble and not readily dislodged. Hence it is found that plumbo-solvent action is comparatively rarely associated with well or spring or river waters, but quite commonly with rain-water or soft moorland waters, especially if they have an acid reaction. Moorland gathering grounds are usually rich in peat, which has an acid reaction, and thus water draining from it is acid and affects lead. Nitrates, chlorides, or excess of carbonic acid or organic matter have been found to increase the corrosion, while silicates and many other substances exert some protective action.

The acid reaction and consequent intense plumbo-solvent effect of certain **moorland waters** has been attributed to acid sulphates (due to the oxidation of iron pyrites, $FeS_2 + H_2O + 7O = FeSO_4 + H_2SO_4$), to sulphurous or other acid in rain, or to the indefinite acid compounds found in soil, and sometimes termed humic and ulmic acid. In some cases it is caused by excess of carbonic acid; but in the main the acidity is that of peat, due, according to Houston, to acid-producing bacteria in the peat. He has shown that a mixture of micro-organisms obtained from peat, when introduced into a sterile decoction made solely from peat, not uncommonly renders the peat decoction acid and plumbo-solvent in character. Acidity in water is more marked in the first flow when rain follows drought, owing, no doubt, to the washing out of the acid accumulated in the peat; and least marked in dry weather, when the contribution from springs is relatively largest. Where peat is abundant, and springs are relatively few and small, acidity and plumbo-solvent ability may be anticipated. But in the absence of carbonate of lime, the power of acquiring lead is shared in considerable degree by many neutral and even slightly alkaline moorland waters, including those in which the acid peat washings have been neutralized by admixture with spring water. Tidy and Odling attributed the lead-dissolving power to the absence of silica, and brought forward evidence to show that this inverse relation holds good in a number of water supplies. There are, however, many exceptions. Even distilled water, or solution of sodium carbonate in distilled water, will attack lead.

In 1887 Sinclair White called attention to the prevalence of plumbism among the consumers of the high-level water at Sheffield, and disastrous consequences have resulted in other Yorkshire towns and elsewhere from the distribution of plumbo-solvent water through lead pipes. In 1908 the Local Government Board furnished particulars of 48 water undertakings in which vigilance was necessary to prevent plumbo-solvency.

Various **remedial measures** have been tried. One plan is to expose the water to fragments of limestone, and conduits have been lined with the same material, but it soon becomes inert, owing to incrustation, and frequent renewal of the surface is necessary.

Measured quantities of lime have also been added (2 to 3 gr. to the gallon). A more effective method is to add powdered chalk or whitening (1½ gr. to the gallon), while in some instances carbonate of soda is used (500 gallons of soda solution, 1 lb. to the gallon, are added to one million gallons of acid water). In pursuance of Tidy's hypothesis, the water has been charged with traces of silica by filtration through powdered granite or flint. Houston recommends ordinary sand-filtration, with the addition of some neutralizing material to the filter (*e.g.* a thin coating of lime on the surface of the sand with limestone underneath the sand) and the subsequent addition of a *trace* of sodium carbonate to the neutral filtered water.

Many waters, fortunately, are sufficiently protected by the salts they contain. Calcium sulphate is less protective than the carbonate, and magnesium less than calcium salts. A crust is formed upon the interior of lead pipes, composed of carbonate and sulphate of lead, lime, and magnesia (or such of them as are present in the water), and chloride of lead. Carbonate of lead is difficult of solution except in water charged with excess of carbonic acid under pressure. Pipes which are new, which are bent against the grain or which are alternately full and empty, are more attacked than others. The maximum amount of lead is found in water that has stood for some time in the pipes, over-night for example.

Many **substitutes for ordinary lead pipes** are now available, and where there is any tendency to solvent action one or other of these should be adopted. Compound pipes have long been in use, the interior of which is block-tin and the exterior lead; the two metals are solidly united throughout, and the pipe can be bent without fracturing the tin. A less reliable protective lining to lead pipes may be found in tar or bitumen. Iron pipes are more satisfactory in every respect, except their rigidity, which renders them difficult to adapt to the bends and turns that are needed in houses. Plain iron pipes may be employed, with some risk of trouble from rusting. Tin-lined, glass-lined, or galvanized iron pipes may be used, and among other protective coatings may be mentioned Angus Smith's varnish and collodion. Theoretically, the rustless Barff iron offers the greatest advantages for this purpose; iron pipes of ordinary construction are exposed while hot to superheated steam, and thereby acquire a thin coating of magnetic oxide, Fe_3O_4, which renders them free from liability to rust as long as the coating is unbroken. Unfortunately the film is easily dislodged in the process of fitting.

If it is not possible to change the supply of water, or to prevent it by chemical means from acting upon lead, or to keep it from coming into contact with lead, recourse must be had to *palliative measures*. The water must always be run off for a few minutes in the morning, and again before drawing it for drinking purposes. All that is used for drinking or for cooking should be filtered through some medium containing animal charcoal. Such filters possess the power of removing lead from solution, owing probably to the phosphates which they contain forming an insoluble lead salt. No water should be used for drinking that contains any trace of lead, for, however minute, its presence indicates danger and it is cumulative in action; moreover, the sample may not represent either the seasonal or daily maximum.

Among the **clinical symptoms of lead-poisoning** are anæmia, depression, dyspepsia, constipation, colic, and paralysis of the extensor muscles of the hand, leading to wrist-drop. A characteristic blue line appears along the edges of the gums, due to the formation of sulphide of lead in the tissue. Optic neuritis may be found. It has been observed that abortion is common in districts where lead-poisoning prevails, and sometimes to such a degree as materially to lower the birth-rate. Occupational lead-poisoning is more frequent and severe than water lead-poisoning (*see* p. 682).

TESTS.* 1. *Qualitative.*—(*a*) H_2S gives a brown tint if a trace of lead is present, and a black precipitate if much; neither is affected by acid. (*b*) A solution of potassium bichromate (1 gr. per oz.) dropped into a tall glass of water, falls slowly, causing an opaque yellow cloud if there is any lead in solution.

2. *Quantitative.*—A standard solution containing 0·1 mg. of lead in 1 c.c. is made by dissolving 0·1831 grm. of crystallized lead acetate in a litre of distilled water. The procedure is the same as in testing for iron, but the water should be made acid.

Acidity of water and *plumbo-solvency* should also be tested for. The former may be estimated by using lacmoid as an indicator. The solution is best made by dissolving 0·2 grm. of lacmoid in 100 c.c. of dilute alcohol (10 per cent.). A few drops added to 10 c.c. of the sample of water at once reveals the presence of the smallest trace of acid. The amount of acid may be determined by titrating a definite quantity of the water with a decinormal solution of sodium carbonate (5·3 grm. Na_2CO_3 per litre).

Plumbo-solvency may be determined in the following way: 50 c.c. (by volume) of washed lead shot are placed in a burette (¾″ × 24″), occupying 18 in. of its length; the sample water is allowed to filter through this lead, and is then collected in successive quantities of 50 c.c., and tested with sulphuretted hydrogen or with ammonium sulphide for the presence of lead.

Zinc, copper, and arsenic, although rarely occurring in natural waters, may occasionally gain access by means of trade pollution, or by the solvent action of water (especially water containing organic matter, nitrites, and nitrates) upon the pipes and vessels with which it comes into contact. Any trace of these substances renders a water unfit for drinking purposes.

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* The sample should be the first pint, *or less*, drawn from the pipe, after standing for an hour or other stated period, if it is to measure the maximum impurity.

TESTS.—Copper, like lead, strikes a black colour with ammonium sulphide, not discharged by acid. It may be determined quantitatively by a colorimetric process similar to those for iron and lead, the standard solution containing 1 mg. of copper in each c.c. being made by dissolving 3·93 grm. of crystallized copper sulphate in a litre of distilled water.

Arsenic would be detected in the residue after evaporation, by the Marsh-Berzelius or other test.

Hardness of water is caused by the presence of salts that decompose soap, preventing lathering until sufficient soap is added to exhaust them. The chief of these are lime salts, magnesium salts, and carbonic acid, but iron and alumina have a similar effect. By boiling the water, the free carbonic acid is driven off, and calcium bicarbonate is reduced to the insoluble carbonate and precipitated; magnesium bicarbonate is precipitated as carbonate in like manner, though it partially redissolves on cooling, and most of the iron is also thrown down. After removal of this *temporary* hardness, there remain in solution calcium and magnesium sulphates and chlorides, and a little iron—assuming them to have been originally present. These, with the re-dissolved magnesium carbonate, constitute the *permanent* hardness. Soap consists of alkaline oleates, stearates, and palmitates, which form a viscid solution in water. The phenomena of hardness depend upon the formation of insoluble calcium and magnesium oleates, etc.

Hardness is measured by a standard soap-solution, 1 c.c. of which exactly precipitates 1 mg. of calcium carbonate. It is found that 1 c.c. suffices to give a lather when shaken with 70 c.c. of distilled water, and anything beyond this is due to the hardness, which is stated in terms of calcium carbonate.

In a bottle of about 250 c.c. capacity 70 c.c. of the water is taken, and the soap-solution is added by degrees from a burette, with vigorous shaking after each addition, until a lather completely covers the surface and remains intact for five minutes. The number of c.c. added, deducting 1 c.c. for lathering, will give the hardness in mg. of calcium carbonate per 70 c.c., that is, in grains per gallon.* The permanent hardness is measured in exactly the same way, in 70 c.c. of the water, after boiling for half an hour and adding distilled water to make good the loss by evaporation. If more than 16 c.c. of soap-solution are consumed by 70 c.c. of water, it is better to dilute it by adding 70 c.c. of distilled water, in which event a deduction of 2 c.c. must be made instead of 1 c.c. for lathering. A "degree" of hardness upon Clark's scale corresponds to a grain of calcium carbonate per gallon.

The disadvantages attendant upon the use of hard water are obvious. There is also some, though by no means complete, evidence of a relation between hard waters and goitre and urinary calculi. A good drinking water should not exceed 4 degrees of permanent, or 20 of total, hardness. It is estimated that each degree of hardness involves a waste of upwards of a pound of soap for every 1,000 gallons used in washing.

ORGANIC MATTER

Organic matter in solution consists of animal and vegetable matters that have gained access to the water, and of the products of their decomposition. Little is known of its chemical composition, the variety and complexity of the components being so great as to defy analysis.

The presence of organic matter (or rather, of oxidizable matter) may be shown by adding a few drops of a solution of potassium permanganate, which is immediately decolorized; or by slightly acidulating the sample water and boiling it for 20 minutes with a few drops of solution of chloride of gold, which will give, according to the amount of organic matter present, a rose, violet, or olive colour, or a violet or black precipitate.

A rough quantitative estimate is obtained by determining the combustible matter in the "total solid residue." Into a platinum dish of known weight A are measured 100 c.c. of sample water. They are then evaporated to dryness over a water-bath (after which the drying should be continued in a water-oven at 100° C. for an hour more), and the weight B of the dish and its now dry contents is ascertained. B − A is the weight of the total solid residue, that is, of the organic matter and mineral salts. The dish is next heated to dull redness, to burn off the organic matter, and weighed again (C) after cooling. The loss on ignition, that is B − C, will give the amount of organic matter in the volume of water taken.* The proportion of organic matter per litre, or per gallon, is readily calculated from these data. Thus,

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* Hardness, unlike other analytical data, is still commonly expressed in grains per gallon. The conversion into the standard terms is readily effected (*see* note, p. 60), for instance, from grains per gallon to parts per 100,000 by dividing by 0·7.

100 c.c.	:	1,000 c.c.	::	B − C	:	x
volume taken.		a litre.		mg. lost on ignition.		

x being the proportion of organic matter expressed as parts per million, or milligrammes per litre. During ignition the organic matter turns brown, or even black, before disappearing, and if of animal origin it gives off pungent fumes.

This method is not sufficiently exact for most quantitative purposes, and recourse is had to other means, of which the chief are :—

1. Wanklyn's ammonia process,
2. Frankland's combustion process, and
3. Forchammer's oxygen process.

None of these professes to give the total amount of organic matter in water, but each fixes upon some one or more element, compound, or property, which is determined with precision and taken as a measure or index of the total organic matter, to which it is assumed to bear a constant ratio.

1 **Wanklyn's ammonia process.** — Most nitrogenous organic matter, when heated with permanganate of potash in presence of excess of potash, gives off a certain proportion of its nitrogen in the form of ammonia. Most, if not all, of the injurious organic impurities occurring in water may reasonably be assumed to be nitrogenous, and, as they yield a definite and fairly constant proportion of their nitrogen as ammonia, we have a very convenient and delicate means of measuring them. It still remains, of course, in this as in all other indirect processes,

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* This is not strictly accurate, since water of crystallisation is driven off from the saline matters, and some small portion of the salts may be volatilised. Carbonates lose CO_2, nitrates are reduced, and chlorine volatilises.

to establish empirical standards of purity, in terms of the ammonia index.

Certain standard solutions are required.

(1) Standard solution of ammonium chloride containing 0·01 mg. of *ammonia* in 1 c.c.

(2) *Nessler's solution* is a saturated solution of mercuric iodide in potassium iodide. It gives a yellowish tinge, with the faintest trace of ammonia, and a yellow-brown precipitate (NHg_2I,H_2O) if more is present.

"Nesslerizing" is a process by which the free or saline ammonia in a sample of water can be readily determined with great accuracy. Two tall cylindrical, flat-bottomed glasses, marked at 50 c.c., are placed side by side upon a white surface. In one of them are placed 50 c.c. of the sample water, and in the other 50 c.c. of distilled water free from any trace of ammonia. Two c.c. of Nessler solution are added to each glass, and the tint struck by the sample is exactly imitated by adding to the second glass successive measured quantities of the standard ammonia solution (*A*) from a burette, until the right tint is reached. Each c.c. of ammonia solution used corresponds to 0·01 mg. of ammonia present in the 50 c.c. of the sample, from which data the amount per litre is readily calculated.

(3) *Alkaline permanganate solution.* Potassium permanganate, 8 grm., and solid caustic potash, 200 grm., are dissolved in a litre of distilled water.

The analysis is conducted as follows:—

Half a litre of the water to be examined, made alkaline if necessary, is put into a large flask, connected with a Liebig's condenser by means of a bent glass tube passing through a perforated indiarubber stopper. The flask is heated by a Bunsen's burner, and the first 50 c.c. of distillate are collected and Nesslerized, and the amount of ammonia they contain is recorded. This ammonia is part of the free ammonia contained in the water as such, and it is found by experience that the first 50 c.c. contain three-quarters of the free ammonia. Hence, adding ⅓ to the amount recorded in the first 50 c.c., we get the whole amount contained in the *half-litre* of water under analysis, and, doubling this, the mg. of free ammonia per *litre*, i.e. parts per million.

Thus, if the first 50 c.c. strike a tint with Nessler, which is matched in the second glass by the addition of 1·2 c.c. standard ammonia solution, we must allow ⅓ of 1·2, that is, 0·4, making a theoretical total of 1·6 c.c. This corresponds to 0·016 mg.

of ammonia in the half-litre taken for analysis, or 0·032 part per million. Meanwhile 150 c.c. more are distilled over, to exhaust the free ammonia, but, as already explained, it is unnecessary to Nesslerize these.

There are then 300 c.c. left in the flask, and to this are now added 50 c.c. of the alkaline permanganate, and the distillation is resumed. The first, second, and third 50 c.c. are collected separately and Nesslerized. Should the third 50 c.c. be found to contain noteworthy quantities of ammonia, a fourth 50 c.c. is distilled over.

The ammonia coming over at this second stage is called *albuminoid ammonia*, being derived from the albuminoid and other nitrogenous organic matter in the water. The second 50 c.c. contain much less than the first, and the third less than the second. Adding together the amount of ammonia found in the three lots, we have the total for the half-litre of water; and twice this will give the proportion in parts per million. Thus,

1st 50 = 2·5 c.c. standard ammonia solution.
2nd 50 = 1·0 c.c. ,, ,, ,,
3rd 50 = 0·3 c.c. ,, ,, ,,

Total = 3·8 c.c. = 0·038 mg. ammonia per half-litre.
∴ Albuminoid ammonia = 0·076 part per million.

Note.—Absence of any trace of albuminoid ammonia is suggestive of organic purity, even if free ammonia and chlorides are high. Albuminoid ammonia less than 0·05 part per million is consistent with extreme purity; and if free ammonia is absent or scanty, albuminoid ammonia under 0·10 is no evidence of impurity. If, however, there is much free ammonia, 0·05 albuminoid ammonia is suspicious, and 0·10 is strong evidence of pollution; 0·15 or more should condemn a water absolutely.

In good waters the free ammonia usually ranges from 0·00 or 0·01 to 0·03 part per million, and rarely exceeds 0·05.

2. **Combustion processes** involve costly and delicate apparatus, and a considerable degree of skill. The following is an outline of Frankland's process :—

To a litre of the water are added 20 c.c. of saturated solution of sulphurous acid, to reduce the oxidized nitrogen and liberate all carbonic acid. The water is evaporated to dryness in special apparatus. The dry residue is mixed with oxide of copper and heated *in vacuo* in a combustion tube for an hour. The gases are collected over a mercurial trough; they contain all the organic carbon as carbonic acid, and the nitrogen as such.

They are measured volumetrically, and after the absorption of the carbonic acid by caustic potash the residue is read as nitrogen. The nitrogen present in the water as ammonia must be separately determined, and deducted from the total.

The significant points are the absolute and relative amounts of organic carbon and organic nitrogen. The lower the proportion of nitrogen to carbon, and the less the amount of each, the more favourable is the verdict, other things being equal. A low proportion of nitrogen to carbon, 1 to 8, indicates vegetable organic matter; a high proportion such as 1 to 3 is pretty certain proof of animal pollution. A river or surface water should not contain more than 0·20 organic carbon or 0·03 organic nitrogen in 100,000 parts, and spring or well water is open to suspicion if the carbon exceeds 0·10, or the nitrogen 0·03, per 100,000. In forming conclusions, due weight must be given to the other analytic data, especially the determination of chlorides and oxidized nitrogen, and to the other evidence obtainable, such as the position and surroundings of the source of supply, the facilities for pollution, and the depth and geological characters of the strata from which it is derived.

The following table, taken from the Report of the Rivers Pollution Commissioners, gives the average results of a large number of samples upon Frankland's method, stated as parts per 100,000 :—

	Rain Water	Upland Surface Water	Deep-Well Water	Spring Water
Total solid impurity	2·95	9·67	43·78	28·20
Organic carbon	0·070	0·322	0·061	0·066
Organic nitrogen ..	0·015	0·032	0·018	0·013
Ammonia	0·029	0·002	0·012	0·001
Nitrogen as nitrates and nitrites	0·003	0·009	0·495	0·383
Total combined nitrogen .	0·042	0·042	0·522	0·396
Chlorine	0·82	1·13	5·11	2·49
Hardness :—				
Temporary	0·4	1·5	15·8	11·0
Permanent	0·5	4·3	0·2	7·5
Total	0·9	5·8	25·0	18·5
Number of samples analysed	39	195	157	198

Kjeldahl's process, applied by Blair to water analysis, is based upon the conversion of the nitrogen of organic substances into ammonium sulphate if charred by heating with strong sulphuric acid: 250 c.c. of water are distilled down to 50, with addition of sodium carbonate if acid; the first 100 c.c. of distillate contains all the free ammonia. Then 10 c.c. of pure sulphuric acid and a little arsenious acid are added, and the distillation is continued. Presently the acid begins to fume, and becomes darkened by the charring of organic matter. The heat is continued for two hours after this, or until the colour disappears again. After cooling, a slight excess of pure solution of soda is added: and the ammonia thus liberated is distilled over, and measured as in Nessler's process.

This method, like Wanklyn's, gives us a record of the "free ammonia" and "organic ammonia" at two stages; but the yield of the latter is more constant and more complete than that obtained with alkaline permanganate. The results are converted into terms of "organic nitrogen" by multiplying by 0·824. Blair finds, by this process, less than 0·06 part of organic nitrogen per million in very pure water, and 0·06 to 0·12 in ordinary drinking-water; he regards as suspicious any water containing more than this, unless peaty, and condemns any over 0·32.

3. **Oxygen process.**—There are many modifications of the Forchammer method, of which Tidy's is the best known. For the sake of uniformity the metric system is substituted for "septems" in the following description:—

The standard solutions required are—

A. Potassium permanganate, 0·395 grm. in a litre of distilled water. Every 10 c.c. yields 1 mg. of oxygen to oxidizable matter.
B. Sodium hyposulphite, 1 grm. per litre.
C. Potassium iodide, 1 part in 10 of water.
D. Starch, 1 part boiled with 20 parts of water, and filtered.
E. Sulphuric acid, 1 part to 3 parts of water.

The object is to determine the amount of oxygen absorbed in 1 hour and 3 hours respectively. As the hyposulphite solution is liable to change, it is necessary to perform a blank test with pure distilled water every time.

Four flasks are employed, two of which contain 250 c.c. of sample water, while the other two contain 250 c.c. of pure water for the control experiments. To each flask are added 10 c.c. of permanganate solution (A) and 10 c.c. of dilute sulphuric acid (E). If the water is very bad, the pink colour due to the permanganate may soon entirely disappear, and in this event a second and even a third 10 c.c. of permanganate must be added, in order always to have a pink tinge throughout the experiment. At the end of an hour one of the samples and one of the control flasks are tested to ascertain how much undecomposed permanganate remains to be deducted from the total used. For this purpose 2 c.c. of iodide solution (c) are added, and the remaining permanganate immediately acts upon it, liberating a proportionate amount of free iodine. The iodine is measured with precision by dropping in the standard hyposulphite solution until no more free iodine remains, the exact point of disappearance of the last trace of iodine being ascertained by adding 2 c.c. of starch solution (D) near the end of the process, and noting the disappearance of the blue iodide of starch.

In the blank test the 10 c.c. of permanganate should remain unaltered at the end of the hour, so that if x c.c. of hyposulphite are used, these x c.c. correspond to 10 c.c. of the permanganate solution, that is, to 1 mg. of oxygen. If, therefore, the sample flask, which has, of course, lost some of its permanganate, takes only y c.c. of hyposulphite, it is clear that the oxygen consumed by oxidizable matter must have been $\frac{x-y}{x}$ mg. If a second 10 c.c. of permanganate had been employed, the formula would obviously have become $\frac{2x-y}{x}$ mg.

As a quarter of a litre of the sample was taken for each analysis, four times this result will give the "oxygen consumed" in milligrammes per litre—that is, in parts per million.

The determination of oxygen consumed in three hours is conducted in exactly the same way, at the end of that time.

Interpretation of results of the oxygen process.—Not only organic matter, but also nitrites, ferrous salts, or sulphuretted hydrogen, will reduce permanganates, and these latter, if present, must be removed or allowed for. No distinction is made between nitrogenous and non-nitrogenous organic matter. In London waters the organic matter is said to be about eight times the "oxygen consumed." It seems that putrescent matters, notably urine and other animal matter, are readily oxidized by permanganate, so that while the three-hours experiment gives information as to the total amount of organic matter, the one-hour reaction is important as indicating the proportion of putrescent and, therefore, presumably dangerous impurities. Sometimes four hours are allowed instead of three, and a quarter or half an hour instead of one hour. Peaty waters consume much oxygen.

As in all other modes of estimating the organic matter in water, the results of the oxygen process must be considered together with the other analytic data and the source of the water. In a general way, Tidy classifies waters as of great organic purity if the oxygen consumed does not exceed 0·5 part per million, of medium purity if not exceeding 1·5 parts, of doubtful purity up to 2·0 parts, and as impure if the oxygen consumed exceeds 2·0 parts per million. Upland surface waters, however (the organic matters being less likely to be harmful), are judged by a more lenient standard, the degrees of which are double those given above, namely, 1·0, 3·0, and 4·0, in place of 0·5, 1·5, and 2·0.

Blair's oxygen process at 100° C. gives very satisfactory results. The reagents are similar to Tidy's, but the following differ in strength:—

Potassium permanganate, 1·975 grm. per litre, so that 10 c.c. yield 5 mg. oxygen.
Sodium hyposulphite, 3·875 grm. per litre.
Sulphuric acid, 100 c.c. to 900 c.c. distilled water.

Half a litre of water is taken for analysis, and, after the addition of 10 c.c. of permanganate and 10 c.c. of acid, is boiled gently for two hours, further charges of permanganate being added if necessary. After cooling, the procedure is the same as in Tidy's process. Iodide is added, and the iodine set free by the unconsumed permanganate is measured by hyposulphite solution with the aid of starch.

The method of calculation also is substantially the same. Since the 10 c.c. of permanganate yields 5 mg. of oxygen instead of 1 mg., the formula becomes $5 \times \frac{x - y}{x}$, or, if n charges of permanganate have been added, $5 \times \frac{x \times n - y}{x}$. This gives the mg. of oxygen absorbed per half-litre, and doubling the result we have mg. per litre, or parts per million. Blair's process has obvious advantages over Tidy's, since the conditions as to temperature are constant, and the oxidation of organic matter is practically complete. The empirical standards of purity necessarily range higher. Exceptionally pure waters take less than 2 parts per million, waters of medium purity 2 to 4 parts, and suspicious waters 4 to 6 parts. Even a peaty water should not be recommended if it takes much more than 6 parts.

Interpretation of the results of water examination.—From what has been said, it will be seen that there are various methods of water analysis or examination by which we may obtain a knowledge of a water sufficient to guide us as to its suitability for drinking purposes. In the past too much emphasis has been given to the results of chemical analysis and too little to the facts obtained by bacterioscopic and microscopic examination, and by inspection of the gathering ground. It cannot be too clearly stated that *all* the facts obtainable respecting a water are necessary to a reliable conclusion. Nothing is more likely to lead to an incorrect opinion than reliance upon isolated findings in respect of a water, whether bacteriological or chemical. The two must be taken together (both quantitative and qualitative) and in conjunction with a careful inspection of the sources, and even then the matter must be judged broadly, and the "life history" of the water taken into consideration.

The chief interpretations of **chemical analysis** have been already referred to in the text, the importance of gases, mineral salts, and soluble organic matter having been dealt with. It is therefore unnecessary to go over the same ground. But it may be added that these general rules are subject to modification according to the history and surroundings of the water. (*a*) Vegetable is much less dangerous than animal contamination, and may often be recognized by the slowness with which the albuminoid ammonia comes over,* by the absence or small amount of chlorides and of free ammonia, and by microscopic examination of the sediment or knowledge of the source of the supply. (*b*) Animal pollution is indicated if the albuminoid ammonia comes over rapidly, or if the chlorides or oxidized nitrogen are abundant. (*c*) It is important to take into

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* The second 50 c.c. containing little less than the first, and the third than the second.

SYNOPSIS OF CHARACTERISTICS OF GOOD AND BAD WATERS

DATA	Pure water	Usable water	Suspicious water	Impure water
A. **CHEMICAL** (*in parts per million*):				
1. **Total dissolved solids**	Under 100.	Under 400.	400 to 700.	Over 700.
2. **Loss in do. on ignition**	Under 15. (*Solids should scarcely blacken on ignition.*)	Under 40. (*Solids may blacken slightly on ignition, but no fumes should be given off.*)	Over 40. (*Much blackening, or nitrous fumes given off.*)	Over 70. (*Much blackening, with nitrous fumes, or smell of burnt horn.*)
3. **Chlorine**	Under 15.	Under 50.	Over 50.	Over 100
4. **Nitrites**	nil.	nil.	Present.	Marked.
5. **Nitrates**	nil, or trace only.	Present.	Marked.	Marked.
6. **Hardness, permanent**	2° Clark.	Under 4° Clark.	Over 4° Clark	Over 6° Clark.
7. **Ammonia, free**	Under 0·02.	Under 0·05.	Over 0·05.	Over 0·10.
8. **Ammonia, albuminoid**	Under 0·05.	Under 0·10.	Over 0·10.	Over 0·15.
9. **Organic carbon**	Under 1·0.	Under 2·0.	Over 2·0.	Over 3·0.
10. **Organic nitrogen**	Under 0·2.	Under 0·3.	Over 0·3.	—
11. **Oxygen taken from acid permanganate**	Under 1·0.	Under 1·5.	Over 1·5.	Over 2·0.
12. **Sulphides (Forchammer)**	nil.	nil.	nil.	Present.
13. **Metals**	nil.	Trace of iron.	Trace of iron.	Much iron. Presence of other metals, especially lead.
B. **PHYSICAL**:				
1. **Transparency**	Clear, bright.	Clear, bright.	Turbid.	Turbid.
2. **Suspended matter**	nil.	nil, or separable by subsidence or coarse filtration.	Much.	Much
3. **Colour**	nil.	faint blue or green tinge only.	Yellowish tinge	Yellow.
4. **Taste**	Palatable.	Palatable.	Any marked taste.	Any marked taste.
5. **Smell**	nil.	nil.	nil.	Any marked smell.
6. **Microscopic characters of sediment**	nil, or as in next column.	Mineral matter. Vegetable form with endochrome. Large animal forms. No organic débris.	Colourless vegetable forms. Organic débris. Fibres of cloth, or other evidence of house-refuse.	Abundant animal and vegetable forms. Fungi. *Beggiatoa.* Epithelial scales. Evidences of sewage Ova of parasites.

the same water supply, or when used in the examination of water before and after filtration. The number of bacteria per c.c. is therefore a fact of only relative importance, because there is no standard of how many organisms should be present in each c.c. of a potable water, and there is no means by which the number can be accurately measured. For purposes of comparison it may be said that the metropolitan water supply, as consumed, usually contains less than 20 bacteria per c.c., and much of it less than 5.

The **organisms which indicate contamination** of a water are certain liquefying bacilli, *B. coli*, *B. enteritidis sporogenes*, and streptococci. The chief of these as an indicator is *B. coli*. It is now held that if this bacillus can be detected in 1 c.c. or 2 c.c. of a water, the organism has gained access recently from sewage. Its relative abundance is a matter of importance. Houston considers the presence of streptococci in water an indication of recent and dangerous pollution. The presence of any pathogenic organisms (*B. typhosus*, the cholera bacillus, etc.), in however few numbers, is, of course, sufficient for the condemnation of a water. Such organisms are rarely isolated from water—even though for external reasons it be evident that the water is the channel of infection—owing to the long incubation period of typhoid fever, the fact that the bacillus only lives in water for a few days, and the impossibility, as a rule, of examining the water which actually caused the outbreak.

Summary.—A water should be condemned, as a rule—(*a*) if it contains a large number of bacteria per c.c. of whatever kind; (*b*) if it contains *B. coli communis*, organisms of "indication," or streptococci, in 1 c.c.; (*c*) if it contains any pathogenic organism; (*d*) if it gives the "enteritidis change" in milk cultures, or ferments glucose or lactose media. In addition to the chemical and bacteriological findings, the careful microscopic examination of the sediment and the thorough inspection of the gathering grounds, the source and course of the water, are necessary. In many ways the latter is the most important part of an examination of a water, and, when in doubt as to chemical and bacteriological characteristics, topography may not infrequently throw light upon the subject.

Drinking water and disease.—The relation of drinking water to typhoid, cholera, diarrhœa, and dysentery will be considered subsequently. Here it is only necessary to add a general note.

Vegetable matter in suspension and even in solution may cause diarrhœa. In small quantity, however, dissolved peaty matter is harmless, although it gives a brownish tinge to the water.

Animal matter in suspension or solution, whether due to percolation from cesspools, leaking drains, farmyards or manured fields, to direct pollution of streams by drains or sewers, or to presence of decomposing animal tissues in the water, or to absorption of effluvia, is always dangerous to health.

The products of simple decomposition of animal matters are in themselves capable of producing diarrhœa and other acute alimentary disturbances, or of insidiously undermining the general health, and so possibly preparing the way for other diseases not directly dependent upon water-borne poison. In tropical countries polluted water is a frequent cause of dysentery, sporadic or epidemic. Sudden localized outbreaks of diarrhœa in Great Britain have been alleged to originate in contamination of drinking water by effluvia from sewage, even without the direct entrance of liquid or solid filth. Apart from all this, the presence of organic filth in water shows that the way is open for the access of more specific poisons, such as those of cholera, enteric fever, dysentery, and parasitical diseases. The tendency of any such pollution is to increase in amount temporarily, while percolation through soil loses in course of time whatever purifying effect it may possess at first.

There are also certain diseases believed to be produced by water owing in part to its mineral or chemical constitution, as, for example, goitre, plumbism, urinary calculi, and possibly cretinism.

Control of water supplies.—The responsibility of the Sanitary Authority in respect to the control and supervision of the water supply within their district will depend in large degree upon the nature of the supply, whether from wells and springs or from a common source. Effective supervision should include—(*a*) a knowledge of the origin, character, and "life-history" of the water; (*b*) the periodical and systematic inspection of the source and gathering ground, including any waterworks, pumps, reservoirs, adits, etc.; (*c*) the chemical and bacteriological examination of the water, sampled from various points of the system; (*d*) the control of any storage-tanks and filter-beds used for purification purposes; and (*e*) periodical inspection of distributive channels, house-cisterns, etc. Much may be done to protect public water supplies from pollution or mismanagement, and still more so the supply derived from wells.

In a memorandum dated December, 1897, addressed to District Councils, the L.G.B. observes:—

"The Council . . . should by careful inquiry make themselves acquainted with the sources, nature, and quality of the water supplies in all parts of their district, and, in every case in which the result of their inquiries is unsatisfactory, should take all such steps as may be within their powers, with the view of supplementing or improving the supplies. . . . Accurate information should be procured, if not already available, in such matters as the following:—

"1. *Where water is derived from gathering ground or from springs.* Whether drainage from human habitations, farmyards, and the like finds its way directly or indirectly into the reservoir or to any part of the water service; and whether risk of access to the water of human excreta and similar refuse is likely to arise.

"2. *Where water is derived from deep wells.* Whether surface or other water liable to be contaminated by drains, sewers, cesspools, and the like reaches, or is liable to reach, the wells. The existence and direction of fissures in the strata deserve a special consideration in this respect.

"3. *Where water is derived from shallow wells.* Whether the wells are so circumstanced that they run risk of contamination by reason of drains, privies, cesspools, or middens, or by deposit of manure—whether derived from human excreta or not—in or on the ground in the neighbourhood of the wells."

In England and Wales the law respecting water supplies is contained in the Public Health Act, 1875, ss. 51–70 and 175 (p. 589), the Public Health (Water) Act, 1878 (p. 191), the Rivers Pollution Prevention Act, 1893 (p. 623), and the Local Government Act, 1894 (s. 8 empowers Parish Councils to provide water supplies). The Metropolis Water Act (p. 191) and the Public Health (London) Act (p. 638) deal with the metropolitan water supply.

In Scotland many of the provisions of these enactments find expression in the Public Health (Scotland) Act, 1897.

CHAPTER IV

FOOD

THE purpose of food in the body economy is threefold—(*a*) the production of heat; (*b*) the production of energy; (*c*) the building-up and repair of the tissues. It is therefore fuel and repair material.

The essential constituents of all food substances, animal, vegetable, and mineral, are classified as—

1. Nitrogenous, including the animal and vegetable albuminoids (proteins) and gelatin.
2. Fatty (including animal and vegetable fats and oils) and carbohydrates (including starch and the sugars).
3. Salts, organic and inorganic.
4. Water.

1. **Nitrogenous food.**—Proteins are converted by the action of the gastric and pancreatic juices into soluble peptones, which are absorbed and used for the nutrition and repair of the nitrogenous tissues, and also in some degree for the production of heat and the functional activity of the system. During life the nitrogen is eventually eliminated in the urine (as urea or urates) and in the fæces. Fat is another product of the splitting-up of albumin, and its hydrogen and carbon ultimately go to form carbonic acid and water. Muscular exertion does not increase the demand for nitrogen or the excretion of urea, these being fairly constant in a given healthy individual under suitable diet, whether working or not. Assimilation of excess of nitrogen, in the absence of

exercise, is apt to lead to imperfect oxidation, with formation of urates and uric acid rather than urea. Other consequences are engorgement of the liver and general plethora, pyrexia, tendency to diarrhœa and, ultimately, to a gouty condition.

Deficiency of nitrogen leads to diminution of circulating albumin, anæmia, loss of weight, and impairment of energy and stamina. Ultimately the tissue albumin, and especially that of the muscles, is reduced.

Nitrogenous food is therefore essential for the growth, maintenance, repair, and functional activity of the tissues, and contributes in some measure to the production of heat and force.*

2. **Fats** and **carbohydrates** supply the oxidizable material for the production of heat and force, and are ultimately eliminated as carbonic acid and water. They aid in the nutrition of the tissues and in the excretion of waste material. An excess of either lessens oxidation of nitrogenous matter and leads to storage of fat in the tissues ; deficiency causes increased metabolism of circulating albumin, loss of weight, and impairment of nutrition. Sugars, starches, and certain other substances are termed *carbohydrates*, because their molecule contains (besides carbon) twice as many atoms of hydrogen as of oxygen, and may therefore be represented empirically as $C_x(H_2O)_n$, or carbon *plus* water. Glucose is $C_6H_{12}O_6$, cane sugar $C_{12}H_{22}O_{11}$, and starch $C_6H_{10}O_5$. Fats and oils (animal or vegetable) contain much less oxygen in proportion to their carbon and hydrogen, stearin, for example, being $C_{21}H_{40}O_6$. Carbohydrates are more readily assimilated than fats, but have a lower nutritive value by at least 40 per cent. They are converted into grape-sugar by the digestive processes. As a rule,

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* Gelatin appears to be capable of replacing the circulating albumin, but not of forming tissue albumin or repairing its waste. Its nutritive value is said to be about one-fourth of that of albumin. Digestion converts it into a sort of peptone, which does not gelatinize.

nutrition ultimately suffers if either fats or carbohydrates are withheld; but to a certain extent they are interchangeable, and the diet of the Eskimo contains little or no carbohydrate.

Fat as a tissue is useful for its mechanical properties—namely, non-conduction of heat, lubrication, and soft elastic pressure; in excess it becomes a source of inconvenience or danger, as in extreme obesity and in fatty infiltration of the heart.

Muscular contraction is the source of animal heat as well as of force, and the heat generated is four times the heat-equivalent of the work done. Although the hydrocarbonous matter supplies the "fuel" for these purposes, it is necessary that a certain amount of nitrogenous matter be associated with it.

3. **Salts.**—Lime, potash, and soda are essential—lime for bone-formation and cell-growth, potash for nutrition of formed tissues, soda for fluid tissues.* Iron in small quantity is required for formation of the colouring matter of the blood (hæmoglobin).

Chlorides and phosphates are indispensable. Salts of organic acids (lactates, tartrates, citrates, malates, acetates), which are oxidized into carbonates in the system, are important as maintaining the alkalinity of the blood.

4. **Water** constitutes two-thirds of the whole weight of the body, and forms part of every tissue. By its agency food is dissolved and carried to the tissues, waste products are removed and excreted, nutrition and chemical changes are rendered possible, and the temperature of the body is regulated by means of evaporation.

Stimulants and condiments are not essential constituents of a complete dietary.

Dietaries.—Hutchison distinguishes four criteria of the value of a dietary—(*a*) chemical, turning upon nutritive constituents as above; (*b*) physical, which measures the value of a food by the amount of heat produced by complete combustion; (*c*) physiological, i.e. assimilability; and (*d*) economic, nutritive value as compared with cost. Only the second of these calls for further comment here. Food material burnt in the body produces the same amount of heat as if burnt in a furnace. Now, the unit of heat-production or fuel value is the kilo-calorie, or as it is generally termed the *Calorie*—that is, the amount of heat required to raise 1 kilogramme (about 2¼ lb.) of water 1° C. Rubner has shown that the heat-value of 1 grm. (= 15½ grains) of protein and 1 grm. of carbohydrate is 4·1 Calories each, and of 1 grm. of fat is 9·3 Calories. Multiplying the percentage of protein and carbohydrate which a food contains by 4·1 and the fat by 9·3 gives the total Calories per 100 parts of the food in question. For example, if 100 grm. of milk contain 2 of protein, 4 of fat, and 6 of carbohydrate, the Calories would be—of protein 8·2, of fat 37·2, and of carbohydrate 24·6, or a total of 70·0 per 100 grm.

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* A vegetable diet calls for additional sodium salts, to make up fo the increased elimination of these due to the excess of potassium salt supplied.

Hopkins has suggested as a standard that whilst 2,500 Calories are necessary for a person at rest or in sedentary occupation, 3,500 Calories are required for a person doing moderate muscular work, and 4,000 or more Calories in hard labour. Chittenden considers that the current estimations of the amount of protein and total fuel-value necessary for hard work are excessive. For hard work all the chief constituents of food may be increased, but there is evidence to show that about 80 per cent. of muscular energy is derived from fat and carbohydrates. For mental work the digestibility of food is of greater concern to the brain-worker than chemical composition (*Hutchison*). Reduction on a muscular diet should, however, affect fats and carbohydrates more than proteins (of which 125 grm. are necessary per man per diem). As already remarked, age and sex exert a marked influence upon dietetic requirements. The same must be said in respect of climate, season, and personal peculiarity.

There are two chief requirements in a nutritious **daily diet** for a healthy man doing a moderate amount of work. First, it must contain food which will provide sufficient energy (average 3,500 Calories); and secondly, it must provide for the upkeep and repair of the tissues of the body (average 125 grm. of protein, 500 grm. of carbohydrates, and 50 grm. of fat). Such a standard, according to Hutchison, yields carbon, nitrogen, and Calories as follows:—

	Carbon (in grm.).	Nitrogen (in grm.).	Calories.
125 grm. Protein . . .	62	20	512·5
500 ,, Carbohydrates	200	..	2050
50 ,, Fat	38	.	465
Total	300	20	3027·5

These quantities may be expressed in English ounces as 4 oz. of protein, 2 oz. of fat, and 18 oz. of carbohydrates, making 24 oz. of dry food daily.

From the chemical standpoint authorities suggest that a daily dietary for a male adult should be composed somewhat as follows:—

	Nitrogenous Food.	Fat.	Carbohydrates.	Salts.	Such a diet would contain	
					Nitrogen.	Carbon.
Rest . . .	3 oz.	1½ oz.	12 oz.	1 oz.	200 gr.	4,000 gr.
Moderate work .	4½ ,,	3 ,,	15 ,,	1¼ ,,	300 ,,	5,000 ,,
Hard work .	6 ,,	4½ ,,	18 ,,	1½ ,,	400 ,,	6,000 ,,

These amounts are only approximate. The necessity for so great an increase of nitrogen during hard work is open to question, and on the other hand the hard-work standard of carbon in the above table is low. More food, especially fat, is needed in cold climates, less in hot.

All the ingredients are supposed to be water-free, but would, in practice, be combined with at least their own weight of water, raising the total daily weight of solid food to 40 or 50 oz. In addition to this 50 to 80

CHEMICAL COMPOSITION (APPROXIMATE) OF CERTAIN FOOD SUBSTANCES (*Parkes*).

	Approx. per cent. of					Grains per lb.	
	Water.	Nitrogenous.	Fatty.	Carbohydrates.	Salts.	Nitrogen.	Carbon.
Good meat,* beef or mutton, with little fat (uncooked)	75	20	5·5	...	1·5	190	1,900
Average meat* (uncooked)	75	15	8·5	...	1·5	...	...
Roast meat	55	28	15	...	3	..	...
Very fat meat*	63	14	19	...	4	..	..
Fat pork	40	10	50	...	2	100	4,000
Salt pork†	45	25	7	...	25	290	1,360
Salt beef†	50	30	0·2	...	20	325	1,115
White fish	78	18	3	...	1	200	875
Eggs	74	14	11·5	...	1	...	...
New milk	87	4	3·5	5	0·5	45	600
Skim milk	90	4	2	5	0·8	45	450
Cheese	37	33	24	...	5·5	300	3,800
Butter	6	0·3	90	...	2·5	...	6,500
Bread	40	8	1·5	50	1·5	90	2,000
Flour	15	11	2	70	1·7	120	2,700
Oatmeal	15	13	6	65	3	140	2,800
Indian meal	14	10	7	65	1·5	120	3,000
Peas (dry)	15	22	2	55	2·5	250	2,700
Green vegetables	90	0·2	0·5	6	0·7	14	420
Carrots	85	0·6	0·2	8·5	0·7	14	500
Potatoes	75	1·5	0·1	23	1	22	770
Rice	10	5	0·8	83	0·5	70	2,700
Sugar	3	...	..	96	0·5	...	3,100‡

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* 20 per cent. should be allowed for bone, and 20 to 30 per cent. more is lost in cooking.

† Brine dissolves out myosin and other important constituents. The nutritive value of salt meat is not more than two-thirds that of fresh meat.

‡ Milk-sugar yields only 2,800 grains of carbon per lb.

oz. of water are taken as drink. A man consumes daily about $\frac{1}{100}$ of his weight of *dry* solid food and $\frac{3}{100}$ of water. Women are said to require about 8 to 10 per cent. less than men, both of carbon and nitrogen. Infants require nitrogenous and fatty foods with only a small proportion of carbohydrates, which is supplied by milk-sugar. A child of 10 years of age needs only half as much, but at 14 years quite as much, as a woman. The dietetic requirements of old age are just the reverse of those of childhood. Growing boys and girls require comparatively more food than adults because their bodies present a greater cooling surface in proportion to weight, and they have not only to make good daily loss of energy but also produce energy necessary for growth.

The table on p. 100 supplies (*a*) types of nitrogenous, fatty, and carbohydrate foods, (*b*) the means of determining how far a given dietary complies with the requirements stated above, and (*c*) the data for constructing a dietary that will satisfy these conditions.

Thus, if the question should arise whether a daily allowance of 2 lb. bread and ½ lb. cheese is a sufficient diet for a man in easy work, the calculation may be made on a chemical basis as follows :—

	Nitro.	Fat.	Carb.-hyd.		Nitro.	Fat.	Carb.-hyd.
100 oz. bread contain	8 oz.	1½ oz.	50 oz.	therefore 32 oz. contain	2·5 oz.	0·5 oz.	16 oz.
100 oz. cheese contain	33 oz.	24 oz.	0 oz.	therefore 8 oz. contain	2·6 oz.	1·9 oz.	0 oz.
					5·1 oz.	2·4 oz.	16 oz.
Whereas the theoretical amounts required for moderate work are . . .					4·5 oz.	3 oz.	15 oz.

The conclusion to be drawn is that such a diet is sufficient as regards the nitrogenous matter and carbohydrates, but wanting in fat.

A still readier method is to calculate the amount of carbon and nitrogen, thus:—

	Nitrogen.	Carbon.		Nitrogen.	Carbon.
1 lb. bread contains	90 gr.	2,000 gr.	therefore 2 lb. contain	180 gr.	4,000 gr.
1 lb. cheese contains	300 gr.	3,300 gr.	therefore ½ lb. contains	150 gr.	1,650 gr.
				330	5,650
The theoretical amounts of carbon and nitrogen required for moderate work being				300	5,000

Hence, if we leave out of consideration the differences between fats and carbohydrates, the diet more than satisfies the theoretical requirements.

The problem may also be presented the other way round. What quantity x of bread and y of cheese would be sufficient for an ordinary diet? The requirements are 300 gr. of nitrogen and 5,000 of carbon; and x lb. of bread contain $90 \times x$ gr. of nitrogen and $2,000 \times x$ gr. of carbon, while y lb. of cheese yield $300 \times y$ gr. of nitrogen and $3,300 \times y$ gr. of carbon. Hence we have a simultaneous equation —

$$\begin{aligned} 90x + 300y &= 300 \\ 2,000x + 3,300y &= 5,000 \end{aligned}$$

giving as approximate values $x = 1{\cdot}7$ lb. and $y = \frac{1}{2}$ lb.

It has been found experimentally that the energy which is developed by oxidation is for one ounce of lean meat about 50 foot-tons,* of carbohydrates 150 foot-tons, and of fats 300 foot-tons. In this relation it should not be forgotten that the oxidation of food in the system is by no means complete, even as regards that portion which is assimilated.

In calculating the **mechanical work** done, that of respiration, circulation, and locomotion must be taken into account, as well as the load carried or lifted. According to Haughton and Parkes the force exerted daily in respiration, circulation, and other "internal" work is about 260 foot-tons; and in addition to this a strong man can do external work equivalent to 300 to 500 foot-tons more per day. Walking along a level road at 3 miles per hour is equivalent to climbing vertically $\frac{1}{20}$ of the distance traversed; at 4 miles, $\frac{1}{17}$. Hence, if a man weighing W lb. carries a load of X lb. on a horizontal track for D feet, at 3 miles per hour, he exerts energy equivalent to $\frac{(W+X)D}{20 \times 2240}$ foot-tons in so doing. A march of 20 miles along the level involves work equivalent to 350 foot-tons, taking the weight of the body as 150 lb. If a load of 60 lb. is added, the work is 500 foot-tons. The whole work done, estimated in this way, represents only one-seventh of the force theoretically obtainable from the food by combustion. The energy expended in a fair day's work is about one-fifth mechanical labour to four-fifths heat (*Martin*). Lindsay, Carver, and Ferguson have shown that the average daily energy-value of the dietary of the labouring class in Glasgow and Birmingham respectively is deficient in Calories.

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* A *foot-ton* is the force required to raise 1 ton to a height of 1 foot.

Relative values of food.—The value of food differs as purchased, as eaten, and as digested. Of 100 grm. of protein swallowed, 2·5 to 25 per cent. passes unchanged through the alimentary canal. This represents therefore a loss, which varies with different foods. The proportion utilized is higher for animal than vegetable food. Benedict calculates that 92 per cent. of protein, 95 per cent. of fat, and 98 per cent. of carbohydrate are digested, and Langworthy has standardized a diet for moderate work thus: As purchased, 3,800 Calories; as eaten, 3,500 Calories; and as digested, 3,200 Calories.

Animal is generally held to possess certain advantages over vegetable food, of which the most certain are the ready supply of blood-pigment, the larger percentage of proteins, the greater digestibility of animal fats, and the smaller bulk required. A vegetable dietary, unless carefully selected, is apt to contain insufficient nitrogen, but it is rich in carbohydrates. It is, however, bulky, less digestible in the stomach, and less completely absorbed. The supposed inferior nutritive value of vegetable albuminoids is not so clear, although they are probably less rapidly digested; and a well-fed vegetable eater may display for a time as perfect health and energy as a meat-eater.* On the other hand, the argument from analogy with the herbivora, some of which are types of activity, loses weight from the inability of man to digest cellulose. The consistent vegetarian must either live on a diet deficient in protein or consume an excessive bulk of food. The adoption of the former course tends to diminish energy and tissue resistance, and the latter is likely to lead to derangement of the digestive organs.

A committee of the Royal Society (1916) have suggested the following methods of economizing the food supply per capita in time of war: (*a*) A better recovery of flour in milling (from 70 to 80 per cent.); (*b*) an increased economy in meat production; (*c*) an increase in protein available for human consumption by increasing the manufacture of cheese, if need be at the expense of butter-making (1 gallon of milk makes ½ lb. of butter or 1 lb. of cheese); (*d*) use as food of materials employed in brewing and distilling; and (*e*) the diversion to human food of some material commonly used for stock-feeding.

Morbid conditions dependent upon diet.—

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* Vegetarianism as ordinarily practised does not exclude animal fats, or even albuminoids; milk, butter, and cheese being used freely.

An excess of food, due to too large or too frequent meals, may accumulate in the intestine, causing fermentation and also dyspepsia, with constipation or ineffective diarrhœa. Gout, obesity, gall-stones, and other conditions may also arise from excess of food. Absorption of the products of putrefaction may give rise to a septic condition marked by pyrexia, furred tongue, fetid breath, heaviness, and possibly jaundice. Diseases of the blood may also be caused by retention of waste products in the intestine, as for instance when chlorosis follows constipation. The effects of excessive or deficient assimilation of nitrogenous and carbonaceous food have already been considered.

Protracted insufficiency of diet is followed by wasting of the tissues (*inanition*). Adipose tissue is naturally the first to suffer, and may be almost completely absorbed, the other tissues following mainly in the inverse order of their importance to life. The urine still contains urea and urates, from oxidation of tissue, first of the circulating albumin, afterwards of tissue albumin. Physical and mental weakness ensue, followed by anæmia and an adynamic condition that powerfully predisposes to certain diseases, notably relapsing fever, phthisis, and pneumonia, and perhaps to all infectious diseases. Diarrhœa is apt to occur, adding still further to the general emaciation and prostration. Ophthalmia, stomatitis, ulcers, and skin diseases of various kinds are common; and any disease that may have obtained a hold upon the system is aggravated by the impairment of nutrition. Death ensues when the loss reaches about 40 per cent. of the normal weight of the body.

Apart from parasitic poison and infection, there are two well-marked morbid conditions that are almost always attributable to the absence of essential elements of diet. These two are rickets and scurvy.

Rickets occurs in children fed upon a diet in which there is undue admixture of starchy food, and a deficiency in fat and proteins. Starch cannot be digested by young infants, and its administration is not only useless but liable to cause diarrhœa, which interferes with the digestion of other food. Prolonged indigestion has much to do with the cause of rickets. Even apart from this, an excess of starch or other carbohydrate has an injurious effect upon nutrition. Lack of fat in dietary and want of sufficient air-space are chiefly responsible for the prevalence of rickets among the poorer labouring classes.

Scurvy does not occur when the diet includes plenty of fresh vegetables and fruits or their juices, or even preserved vegetables and fruits. The blood or raw flesh of recently killed animals is credited with considerable anti-scorbutic power. Citrate, tartrate, and malate of potash are also preventives, and, to a less degree, lactate and acetate. Carbonate of potash is inert. The disease affects underfed men more readily, but cannot be checked by increase in the supply of nitrogenous food, carbohydrates, or fat. The fault probably rests with the supply of salts, and, as scurvy occurs when there is no lack of phosphates or sodium chloride, potash and organic acids alone of the ordinary salines are missing. The salts of organic acids differ from those of mineral acids in one important particular, namely, their oxidation in the blood to form carbonates with alkaline reaction, although they may have been neutral or acid originally. Thus the citric acid and citrate of potash, which are the principal constituents of lime-juice, are oxidized into carbonic acid, which is removed by the lungs, and (alkaline) potassium carbonate. Potatoes are efficient antiscorbutics, and contain a large proportion of organic acid, salts of potash, soda, and lime. The absence of land scurvy at the present time may not unreasonably be attributed in great measure to the universal use of potatoes, and other fresh vegetables and fruits, as articles of food.

MEAT

The variations in the nutritive qualities of meat depend upon the age of the animal, the state of its nutrition at the time of slaughter, and the proportion of fat. Well-fed prime meat contains more albuminoids and less connective tissue than that which is taken from animals that are badly fed, diseased, or too old or too young. The proportion of fat, roughly speaking, ranges from 50 per cent. in fat pigs or sheep to 33 per cent. in fat oxen or lambs, and 16 per cent. in calves. Absence of fat is largely compensated for by presence of additional water, so that the nitrogen remains fairly constant. As a rule, "white meat," such as fowl and rabbit, is less nitrogenous, more tender, and more digestible than "red meat," such as beef, mutton, and game. The latter become more tender if kept until *rigor mortis* gives place to incipient putrefactive changes.

Relation to disease.—The flesh of animals suffering from any inflammatory disease is watery and innutritious, discoloured, possesses a stale odour, and decomposes rapidly. The use of such meat is liable to cause alimentary disturbance. The same applies, more or less, to animals emaciated from any cause. In some persons acute dyspepsia and diarrhœa are caused by apparently normal meat of certain kinds, usually pork or mutton. As a rule, meat in any stage of putrefaction (the signs of which are smell, discoloration, and loss of elasticity) is liable to cause acute gastro-intestinal irritation, and other manifestations of septic poisoning, the prominent symptoms being vomiting, diarrhœa, cramps, prostration, pyrexia, with weak and irregular pulse. Meat in an early stage of decomposition is frequently more toxic than when more advanced. It is not, however, easy t account for the impunity with which certain kind of food, venison and game for instance, are habituall consumed in a state of early decomposition. It i probable that the toxic products are not present i anything like the same degree as in ordinary meat and it is possible that such products, and eve the causal organisms, are different. Certain parasites, to which further reference is made in a late section, are clearly transmissible to man, and therefor suffice to render the whole carcass unfit for food ; th chief being the *Tæniæ* in beef, mutton, and pork and *Trichinæ* in "measly" pork. Sheep are liable t *Strongylus filaria* in the lungs, *Distoma hepaticum* i the liver, and *Cœnurus cerebralis* in the brain ; bu the presence of these is held to require only th removal of the affected organs.

Accident, parturition, or purely local diseases, suc as apoplexy or intestinal obstruction, do not necessarily render a carcass unfit for food, provided tha the animal has been slaughtered before any inflammatory or other constitutional mischief has occurred An animal that has died with the blood in it i presumably diseased, and it is customary to condem such a carcass on that account, and because decomposition rapidly sets in. The flesh of animals affecte with any acute specific disease should be rejected, no only upon the grounds already stated with reference t inflammatory diseases, but also on account of the ris of imparting the specific malady. Anthrax has bee thought to be so transmitted, and there is strong suspicion that actinomycosis has been similarly conveyed. Generally, it may be said that the transmission o disease by meat foods is best illustrated in bacterial food-poisoning and tuberculosis.

Bacterial food-poisoning.—At Welbeck Notts, in June, 1880, a large number of persons were taken ill after eating some ham at a public luncheon. Ballard found that this was the only condition common to all the sufferers. The onset occurred in some cases suddenly, for the most part between twelve and thirty-six hours later. The symptoms included violent diarrhœa, vomiting, and abdominal pain, usually accompanied or followed by pyrexia, thirst, headache, cramps in the limbs, cold sweats, and great prostration. Particulars were obtained of 72 cases, of which 4 were fatal. The ham was observed to have a disagreeable taste, but was not suspected to be tainted. It had been exposed to sewer air. Klein found spores and bacilli in the muscular fibres of the suspected ham, and similar bacilli in the kidney of a man who died of the disease. Dogs, cats, rabbits, guineapigs, and white mice were fed upon the ham, and nearly all developed pneumonia and other symptoms; inoculation of white mice and guineapigs gave the same result. Cultures were made, and guineapigs and white mice which were fed or inoculated therewith presented the same symptoms.

A second series of cases occurred in Nottingham, in February, 1881, among persons who had partaken of some hot baked pork. Fifteen were attacked, and one died. The time and mode of onset, and the general character of the symptoms, were similar to those noted in the Welbeck outbreak. Not all the persons who ate of the pork were taken ill. Klein examined the tissues of the fatal case referred to above, and found the Welbeck bacilli in the blood, pericardial fluid, lungs, spleen, kidney, and elsewhere. Cultures inoculated into mice and guineapigs caused pneumonia and other symptoms in all; and the bacilli were found in the blood and exudations.

These two outbreaks drew attention to the whole question of meat poisoning. In 1888 Gaertner isolated *Bacillus enteritidis* from meat poisoning cases, and in 1896 Ermengem discovered *B. botulinus* in sausage-poisoning cases. Since 1880 a very large number of such epidemics have been investigated. Some of the more typical outbreaks in this country may be tabulated thus:—

Date of occurrence.	Place of occurrence.	No. of cases.	Period of incubation in hours.	Probable source of infection.
1880	Welbeck	72	12-48	Cold boiled hams
1881	Nottingham	15	12-34	Pork
1882	Whitchurch	20	1-5	Brawn
1886	Carlisle	20	6-40	Ham & game pie
1887	Retford	80	8-36	Pork brawn
1889	Carlisle	25	24	Pork pies
1896	Mansfield	265	18-24	Potted meat
1898	Hatton	185	..	Veal pies
1898	Chadderton	54	6-7	Veal pies
1899	Nuneaton	42	5½-48	Pork
1899	Sheffield	24	2-3	Corned beef
1902	Derby	221	1-24	Pork pie
1906	Bedfordshire	29	8-24	Pork pie
1907	Wigan	168	36	Potted tongue
1907	Tollesbury	80	1½-4	Brawn
1908	St. Anne's-on-Sea	76	2-12	Potted beef and pork pies
1908	Limerick	73	6-12	Beef
1910	Warwick	20	20	Boiled beef
1910	Wrexham	107	5-45	Pork pies
1911	Chesterfield	168	..	Pork pies
1911	Bacup	213	4-20	Brawn
1912	Chorley	241	..	Pork pies
1912	Manchester	163	..	Pork

Each outbreak has shown more or less clearly the characters common to these epidemics—1, simultaneous attacks; 2, similarity of symptoms and post-mortem signs; 3, a history of infection in common. The usual symptoms include rigors, faintness, vomiting, diarrhœa, abdominal pain, and occasionally skin eruptions. As a rule, certain nervous conditions have supervened, such as giddiness, headache, prostration, mental depression, etc., and occasionally these symptoms have been predominant.

Meat poisoning may be due to (*a*) chemical poisons such as lead or arsenic (from tinned goods, etc.); (*b*) specific infective diseases, e.g. septicæmia or tuberculosis; or (*c*) bacteria or their toxins. The third group is that now described as "bacterial food-poisoning." The incubation period is short, 6–12 hours. In general, bacterial poisoning (infection) manifests a longer incubation period than toxin poisoning (intoxication), and the longer the period from initial contamination to the consumption of the food the shorter the incubation period. Secondary infection is rare, and there is no special incidence on age or sex. The infectivity-rate is high, and the fatality-rate varies widely. Outbreaks of this kind occur most commonly in the summer. The poisonous meat is usually derived from pigs or cattle. The bacteria concerned in food poisoning are classified by Savage in three groups:

(i.) The Gaertner group—*B. enteritidis*, *B. suipestifer*, *B. paratyphosus* B, *and B. morbificans bovis*.

(ii.) The non-Gaertner group—*B. proteus*, *B. coli*.

(iii.) *B. botulinus*.

Bainbridge showed that paratyphoid fever (*B. paratyphosus*, A and B) is a morbid condition separate from meat poisoning, having a longer incubation period, and being an infection similar to typhoid and conveyed by human carriers. The evidence implicating *B. proteus* and *B. coli* in meat poisoning is not conclusive. They may be organisms of association only. Botulism is extremely rare in this country.

B. enteritidis (Gaertner). Characters similar to *B. typhosus* (morphology, motility, and staining properties), but grows more rapidly in gelatin; fewer flagella; ferments lactose and sometimes dextrose; does not produce indol or coagulate milk; positive neutral-red reaction; in litmus whey or litmus broth, acid is first produced, and then the medium becomes distinctly alkaline. Virulent to rodents and small animals (gastro-intestinal symptoms, hæmorrhagic enteritis and swelling of lymph follicles). Forms no spores, and therefore cannot stand very high temperatures (killed at 70° C. in one minute). It produces agglutinating properties in the blood of the patient and is separable from paratyphoid bacilli by this test. Multiplies with great rapidity in meat foods, and can thrive in such media for long periods.

B. botulinus (Ermengem). Van Ermengem describes, under the name of botulism, a state brought about by the ingestion of various articles of food, such as ham, tinned or preserved foods, oysters, mussels, etc., and characterized by comparatively slow onset (12–24 hours after infection), secretory troubles, paralysis of certain muscles, particularly of tongue and pharynx, dilatation of pupil, aphonia, dysphagia, constipation, retention of urine, absence of unconsciousness and of fever, etc. Botulism differs considerably from the more common form of food-poisoning with which we are acquainted in England, and which is characterized by practically the same symptoms as those of epidemic diarrhœa. *B. botulinus* is 4–9 μ long and 0·9–1·2 μ broad; round, slowly motile, 4–9 flagella. Polar spores, killed in thirty minutes at 80° C. Liquefies gelatin; does not coagulate milk; anaerobic; in cultures often produces gas and a sour, rancid odour. Pathogenic for guineapigs, rabbits, and other small animals.

B. enteritidis sporogenes of Klein, *see* under Epidemic Diarrhœa, p. 449.

It is now well established that the majority of the recognized outbreaks of meat-food poisoning are caused by the *B. enteritidis* of Gaertner. Delépine held that in the Derby outbreak (1902) the presence of the bacillus in the pork pies was due to contamination of the meat before it was cooked, and that the central parts of the pies were not thoroughly cooked. It frequently happens in these cases that some constituent part (such as jelly) of the manufactured article or prepared dish is really the polluted portion. Experience of meat-poisoning outbreaks leads to the conclusion that the meat has contracted its poisonous properties in one or all of the following ways, viz. specific infection from animals suffering from disease, putrefaction or unsoundness in the meat, unclean preparaion or storage in insanitary places, or insufficient cooking. The **methods of prevention** are therefore obvious, namely: (*a*) meat inspection, (*b*) separation of slaughter-houses from preparation premises, (*c*) cleanliness in preparation, and (*d*) notification of outbreaks.

Where the **M.O.H.** becomes aware of the occurrence of a considerable number of cases of food poisoning in his district, he should report it forthwith to the **L.G.B.** (*see* Article xix. (15) of the L.G.B.'s General Order of December, 1910, and Article 18 (16) of the Sanitary Officers (London) Order, 1891); and he is, moreover, required by Article xix. (16) of the Order to furnish to the Board a copy of any special report or reports which he makes to his Authority on the results of his inquiries into the outbreak.

Tuberculosis.—This disease is set up in animals by the tubercle bacillus, which is either identical with or an allied form of the *B. tuberculosis* of Koch.

Tuberculosis is common among cattle, especially if stall-fed, and is increased by the practice of housing them with inadequate air-space and ventilation. The tuberculin test has revealed the presence of tuberculosis in 30–50 per cent. of the cows of certain breeds in certain dairies. Investigations carried out in 1902 in all the chief breeds in this country showed that 14·7 per cent. are affected with tuberculosis (*Geddes*). Probably the general average is about 15–20 per cent. In London and other large cities, where a high degree of inspection is maintained, and where there is no in-breeding, a very small and negligible number of the cows are tubercular.

It has long been customary to condemn as unfit for food all parts of a carcass in which tubercle is found, and the whole carcass if the disease be far advanced and the animal emaciated. Following the conclusions of the Paris Congress of 1888, many Authorities have adopted a more stringent standard, and condemn the whole carcass if there be any tubercle in any part, no matter how slight or localized.

The Royal Commission on Tuberculosis (1895) reported in 1898 as follows:—

"The following principles should be observed in the inspection of tuberculous carcasses of cattle:—

(*a*) When there is miliary tuberculosis of both lungs . .	Generalized tuberculosis is present, and the entire carcass and all the organs may be seized.
(*b*) When tuberculous lesions are present on the pleura and peritoneum	
(*c*) When tuberculous lesions are present in the muscular system, or in the lymphatic glands embedded in or between the muscles	
(*d*) When tuberculous lesions exist in any part of an emaciated carcass	
(*a*) When the lesions are confined to the lungs and the thoracic lymphatic glands . . .	Localized tuberculosis is present, and the carcass, if otherwise healthy, shall not be condemned, but every part of it containing tuberculous lesions shall be seized.
(*b*) When the lesions are confined to the liver	
(*c*) When the lesions are confined to the pharyngeal lymphatic glands	
(*d*) When the lesions are confined to any combination of the foregoing, but are collectively small in extent . .	

"In view of the greater tendency to generalization of tuberculosis in the pig, we consider that the presence of tubercular deposit in any degree should involve seizure of the whole carcass and of the organs.

"In respect of foreign dead meat, seizure shall ensue in every case where the pleuræ have been 'stripped.'"

The tubercle bacillus is most easily found in the glands, and tuberculous deposits in the muscles are very rare. The bacillus is scarce in the caseating nodules. In the pig it is difficult to detect the bacilli, as a rule, though the disease is very common in that animal, affecting chiefly the abdominal organs and the glands of the throat. It is rare in the sheep. The Royal Commission reported that "in tissues which go to form the butcher's joint, the material of tubercle is not often found even where the organs (lungs, liver, spleen, membranes, etc.) exhibit very advanced or generalized tuberculosis; indeed, in muscle and muscle juice it is very seldom that tubercle bacilli are to be met with; perhaps they are somewhat more often to be discovered in bone, or in some small lymphatic gland embedded in intermuscular fat." The chief way in which such meat substance becomes infected with tubercle appears to be through carelessness in the butcher, who perchance smears the meat substance with a knife which has been used in cutting the organs, and so has become contaminated with infected material. "Ordinary cooking, such as boiling and more especially roasting, though quite sufficient to sterilize the surface, and even the substance for a short distance from the surface of a joint, cannot be relied upon to sterilize tubercular material included in the centre of rolls of meat, especially when these are more than three pounds or four pounds weight. The least reliable method of cooking for this purpose is roasting before a fire; next comes roasting in an oven, and then boiling." (*Sims Woodhead.*)

It should be added that whilst it is evident that tuberculosis is not greatly spread by the consumption of tuberculous meat, the Royal Commission of 1895 definitely concluded that "we must believe that any person who takes tuberculous matter into the body as food incurs some risk of acquiring tuberculous disease." In spite of Koch's views to the contrary, which are discussed subsequently, that conclusion still represents, broadly, the views of most authorities (*see* p. 474).

The Tuberculosis Order, 1913, issued by the Board of Agriculture, requires notification of any cow which is, or appears to be, suffering from tuberculosis of the udder, indurated udder, or other chronic disease of the udder; or any bovine animal which is, or appears to be, suffering from tuberculosis with emaciation. The notification must be made by the owner or by any veterinary surgeon. Power is also given for veterinary examination, application of tuberculin test, and sampling of discharges, etc., for diagnostic purposes. Where the Authority are satisfied of the existence of such disease or of a cow giving tuberculous milk, they must arrange for its slaughter with due compensation (one-quarter to three-quarters its value) under prescribed conditions. Provision is also made for the detention and isolation of suspected animals at fairs, sales, and markets.

Characters of good meat.—It should be firm and elastic, but not tough, and it should not "pit" on pressure; a thin red meat juice (acid) will often exude in small quantity on standing; the meat substance should be red throughout, not pale, purple, or green; marbled by layers of fat; free from purulent or gelatinous fluid in the septa between the muscular bands; fresh and pleasant in smell, as tested by a clean skewer which has been plunged into the interior. The reaction should be slightly acid. The meat should "set" within twenty-four hours.* The flesh is pale in pork, in young animals, and in those suffering from exhausting diseases; dark in old animals, and those which have died with the blood in them, and in inflamed parts; wet in dropsy, and often in inflammatory diseases. With commencing putrefaction the colour becomes pale, and the smell disagreeable; later the meat softens in parts and turns green.

The liver, lungs, heart, and flesh should be examined for parasites; the head, stomach, and intestines for evidences of specific disease. The microscope would detect *Cysticerci* (usually visible to the naked eye) and *Trichinæ* in muscle, and *Stephanurus dentatus* in the brain. To demonstrate *Trichinæ*, a thin section should be put into liquor potassæ for a few minutes only until the muscle becomes translucent. The coiled embryo will be seen inside the capsule.

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* Horse flesh may be differentiated from beef by the following characters: It does not set so rapidly or so well. It is more tendinous and fibrous, contains less fat, which is oily and yellow, and possesses a horsey smell. The colour is also more brown-red and less bright than in sound beef.

The fat should be firm, white, and free from hæmorrhages ; not yellow or gelatinous.

Fat consists of olein, palmitin, and stearin, which are respectively oleic acid, palmitic acid, and stearic acid, combined with glycerin as a base. Stearin, $\left.\begin{matrix}(C_{18}H_{35}O)_3\\C_3H_5\end{matrix}\right\}O_3$, melts at about 65° C.; palmitin, $\left.\begin{matrix}(C_{16}H_{31}O)_3\\C_3H_5\end{matrix}\right\}O_3$, at a variable point between 35° C. and 60° C.; olein, $\left.\begin{matrix}(C_{18}H_{33}O)_3\\C_3H_5\end{matrix}\right\}O_3$, at 5° C. Fats with a high melting-point, such as mutton fat, consist mainly of stearin; those with a low melting-point, such as bacon fat, principally of olein

Sausages are liable to convey the same diseases as the meat from which they are made, but there are no longer any macroscopic signs to guide us. In a fatal case at Chester, investigated by Ballard, violent symptoms of gastro-intestinal irritation came on within half an hour of eating sausage which was found to contain an organic-chemical poison. There have since been similar cases. Decomposition may be detected by the smell, which is made more obvious by adding hot water and lime-water.

Preservation of meat may be effected for a time—

(1) By exclusion of air. The meat is dipped into boiling water so as to form an impervious layer of coagulated albumin on the surface; or coated with paraffin, or simply with fat.

(2) By injection of preservative solutions. The blood-vessels are injected first with water, then with a

solution of alum and aluminium chloride—or even sodium chloride.

(3) By application of preservatives to the surface. The meat may be covered with salt, sugar, boric acid, boroglyceride, powdered charcoal, weak carbolic acid, or other fixed antiseptic. Or it may be kept in a closed vessel containing volatile oils or antiseptics.

(4) By pickling. Common salt, with a little potassium nitrate, is rubbed into the meat, or the latter is immersed in strong brine. Water is abstracted, and the salt acts as a preservative.

(5) By drying. Meat is exposed in somewhat thin layers to dry air, or, still better, to the smoke from a wood fire.

(6) By continuous exposure to cold (*freezing*). Meat can be kept in a cold-air chamber for an indefinite period, but decomposes rapidly upon thawing if *rigor mortis* had set in before freezing. It is better to keep the temperature a little above freezing-point (*refrigerated* or *chilled* meat), as actual freezing has certain disadvantages.

(7) By hermetically sealing in tin cases or other vessels *in vacuo*, or in sterilized air. Various devices are adopted to sterilize the contents of the tins. Before sealing, air may be drawn off and replaced by nitrogen and sulphurous acid, or by air which has been heated to 500° F., or by steam. Other processes aim at complete exclusion of air, or exclusion of part and removal of oxygen from the remainder by means of sodium sulphite, or at exclusion of all germ-life by boiling.

The dangers attending the use of preserved meat are those depending upon the original character of the meat, already referred to, together with risk of putrefaction if the process is imperfectly carried out. Tinned meat sometimes gives rise within twelve hours to symptoms of acute gastro-intestinal irritation, viz vomiting, purging, cramps, some degree of pyrexia, irregular pulse, and prostration. These ill effects may result from decomposition due to imperfections in the process; and in this case the tin will show signs of pressure in place of the usual vacuum ("blown" tins), and the meat may have an offensive smell and taste. Not infrequently, however, no such changes are noticed, but salts of tin, zinc, or lead are found in the meat and jelly, due, no doubt, to the action of sodium chloride or organic acids upon the tin or solder, perhaps aided by galvanic action. Dangers arising from the consumption of tinned food are due to changes in the food itself, the use of preservatives or colouring agents, or defects in the canning.

Cooking brings about coagulation of the myosin and other albuminoids, renders the meat soft and tender by converting the connective tissue into gelatin, and reduces the amount of water and extractives. Boiling in the ordinary way causes a loss of 25 per cent. or more, but most of the salts and soluble substances may be retained by plunging the meat for five minutes into boiling water, and then continuing the cooking at a low temperature. The loss is greater in roasting than in baking, and least in boiling. The various albuminoids coagulate at temperatures ranging from 85° to 170° F., hæmoglobin at 160°. If, therefore, the temperature at any part does not reach 160° the meat is underdone; and if it exceeds 170° the tissues shrink and become hard and indigestible. The best temperature is about 160°. Roasting also entails a loss of about 25 per cent., but mainly of water, with some fat and a little gelatin. It is advisable first to expose meat to an intense heat and afterwards cook it slowly. Ordinary cooking or pickling affords little protection in meat infected with specific virus.

Meat inspection. — The effectual inspection of meat really requires (*a*) veterinary inspection of animals before slaughter, and (*b*) systematic inspection in some form of clearing-house of all market meat. In the absence of these two requirements, meat inspection must necessarily be incomplete. In some countries there is State inspection, and all marketable meat bears an official stamp. In this country, however, the duty of meat inspection rests mainly with the Local Authorities, the larger of which employ Meat Inspectors specially qualified for the work.

Qualifications of Meat Inspectors. The **L.G.B.**, in circular letters addressed to Local Authorities in 1899 and 1901, strongly urged that Meat Inspectors should be directed to act in accordance with the principles laid down by the Royal Commission with regard to the condemnation and seizure of meat affected with tuberculosis (p. 114), and, further, that they should possess proper qualifications for the office, including acquaintance with—

(*a*) The law of meat inspection.
(*b*) The names and situations of the organs of the body.
(*c*) Signs of health and disease in animals destined for food, both when alive and after slaughter.
(*d*) The appearance and character of fresh meat, organs, fat and blood, and the conditions rendering them, or preparations from them, fit or unfit for human food.

Any Inspector of Nuisances or Sanitary Inspector to whom either of these orders applies is required in any case of doubt in connexion with the inspection and seizure of meat to report the matter to the Medical Officer of Health, with the view of obtaining his advice thereon.

Methods of inspection. Cursory inspection will frequently mislead, and it is desirable for the Meat Inspector to perform his duties in a systematic manner. At the slaughter-house or in the wholesale market, meat may be examined as follows (written notes being made):—

(*a*) *Inspection of the carcass.*—Note in particular the species of animal, the general character of the carcass, size, weight, emaciation, the condition of the bones, the pleura (and whether "stripped" or not), the peritoneum, the kidneys, the superficial and deep glands, the colour and condition of the flesh (to be judged by the freshly cut surface), staining of the peritoneum owing to decomposition in the intestine, signs of dropsy or inflammation, signs of drugging, etc.

(b) *Inspection of the organs (constituting the "offal")*.—The head: the heart, lungs and liver ("plucks"): the spleen, udder, stomach, and intestines, should each be examined if available.

(c) *The mode of dressing the carcass.*—Artificial inflation of emaciated tissues by air, the smearing of fat over the surface of the carcass, stripping of the membranes, skilful dressing of the carcass, and evident preparation of it for market, should all be noted. Sometimes methods are adopted to disguise the real condition of meat on the one hand, and, on the other, meat for human consumption is dressed to a marketable standard.

(d) *Miscellaneous.*—In addition to the condition of the meat itself, there are other matters not to be neglected by the Meat Inspector, such as the price marked upon the meat, whether it was exposed for sale, or deposited for the purpose of sale, or deposited for preparation for sale, the hour at which it was inspected (or subsequently seized), the condition and temperature of the atmosphere, etc. All these may become of importance in any subsequent proceedings.

(e) *Inspection of foreign meat.* — Under the Public Health (Food and Meat) Regulations, 1908 (p. 644), additional duties of meat inspection are imposed upon the **M.O.H.** or any duly authorized person. This foreign boneless and "boxed meat" is imported in boxes in the frozen state from the United States, New Zealand, Australia, and Argentina. Some of it arrives preserved in boric acid in barrels, or frozen in bags. The pieces of meat are often packed tightly together and form a solid mass, or so rolled and folded as to make identification and examination impracticable. The condition of such meat must be judged on broad general lines, and chemical analysis made when necessary. Special attention should be directed to tripe, tongues, kidneys, or pieces imported in "sweet pickle" or "patent pickle." If tuberculosis be found to be present in any degree in pig carcasses the whole carcass should be condemned. Facilities should always be provided to the importer or vendor to have the meat examined on his own account (*see* p. 645).

Mode of proceeding.—An Inspector who comes across unwholesome meat should (*a*) "seize" it, unless it be voluntarily surrendered by the owner taking the initiative, and (*b*) inform the **M.O.H.** If the **M.O.H.** considers the meat unfit for food, (*c*) it should at once be submitted to a magistrate for condemnation and destruction, the owner being permitted to have the meat seen by experts on his behalf if he so wishes. (*d*) The case should be fully reported to the **S.A.**, and instructions may be taken as to proceedings. The portions of evidence which may be required in court are as follows: (i.) A copy of the summons issued by the **S.A.** against the owner of the meat; (ii.) the order signed by the magistrate to the effect that, having examined the meat, he had ordered its destruction; (iii.) the resolution of the **S.A.** or Committee, signed by the chairman; (iv.) copies of subpœnas; (v.) a clear and concise statement of the Inspector's evidence of seizure and the reasons for seizure; (vi.) a statement by the **M.O.H.** as to the pathological condition of the meat in question and its unfitness for human food; (vii.) collateral evidence of medical or veterinary experts, if such are to be called, and of other persons, salesmen, porters, butchers, slaughterers, etc.

Classification of unwholesome meat. — Before forming an opinion as to unwholesomeness of meat, it is necessary to decide as to its quality and condition; that is, whether it is fresh home-grown meat or frozen, chilled, salted, or pickled meat. Having assured himself of the conditions under which the meat is being examined, the next step for the Meat Inspector is to diagnose the disease with which the meat is affected. Broadly, and for practical purposes of meat inspection, these may be divided into three groups—(*a*) general pathological conditions; (*b*) specific disease; (*c*) decomposition. Among the *general pathological conditions* are ordinary degeneration of the tissues and inflammation: fatty infiltration, calcification, and infiltration by pigment, as in melanosis and jaundice; cloudy swelling, fatty degeneration, amyloid disease, gangrene, etc.; fevered flesh, and the meat of unbled animals that have died, or have been slaughtered when in a moribund condition. The last named is blood-stained, sticky, pits on pressure, and possesses a uræmic smell. It rapidly decomposes, and is heavily charged with toxic properties. There are a variety of inflammatory diseases, some of which are doubtless due to specific causes, and others of which the origin is obscure.

Secondly, there are the *specific diseases of animals* which cause meat to be unfit for food. These diseases are not necessarily transmissible to man, but they produce in the tissues of the animals suffering from them certain poisonous toxins. It should be remembered that in many cases such products occur early in the disease, and not only when it has reached an advanced stage. Among specific diseases for which meat should be seized as unfit for food are tuberculosis, actinomycosis, glanders, anthrax, swine fever, contagious pleuro-pneumonia, septicæmia, cattle plague, and a large number of parasitical diseases.

Decomposition of meat is, of course, a post-mortem change. The rapidity with which the decomposition sets in depends upon many circumstances external to the meat, such as temperature of the air, place of storage, etc. Colour, consistence, and odour are the three chief signs upon which reliance may be placed. Mouldy meat, if otherwise good, need not be wholly condemned. Such moulds frequently consist of penicillium, mucor, cladosporium ("black spot"), coloured bacterial growths, etc. Mould contamination is liable to occur when meat has been improperly handled or stored. There is no evidence that such moulds or their products are toxic, though mouldy meat should be carefully examined for decomposition.

In 1911 the **L.G.B.** issued a Memorandum on the investigation of outbreaks of food poisoning, in which the following **scheme of inquiry** was recommended :—

What cases heard of; steps taken to secure complete list of cases, e.g. inquiries of medical practitioners, neighbouring medical officers of health, and others.

Evidence implicating particular food or foods as cause of outbreak.

Evidence implicating any particular ingredient of the food.

Origin of suspected food or ingredient.

Inquiries in Affected Households

Names and ages of persons (*a*) in each household, (*b*) those ill, (*c*) those partaking of suspected food.

Persons affected—(*a*) slightly, (*b*) seriously, (*c*) fatally: with date and hour of partaking of food in each case, and date and hour of first symptoms in each case.

Clinical character of illness.

Particular food implicated. Date of purchase, source; any form of domestic preparation applied (e.g. cooking); if so, how long and to what degree; if canned meat, when opened, etc.

Inquiries at Place of Preparation (when Food implicated has been prepared in the District)

Address or description of place of preparation; name and address of owner or occupier; number of workers employed (male and female); nature of employment in each case. Any engaged also in other employments which might have connexion with contamination of the suspected food.

Meat concerned; its nature, where obtained, amount used on days concerned, how and where stored.

Evidence, positive or negative, of unsoundness of the meat.

Evidence, positive or negative, as to disease of animal during life or ascertained post mortem.

Possibilities of infection at slaughter-house or place of storage.

Sanitary condition of bakehouse or food-preparing place (including distance from possible sources of contamination, e.g. middenstead, ashpit, privy, w.c.; slaughter-house, stable), positions of drain openings; ventilation; general sanitary condition (*See also* p. 680.)

Cleanliness of tables, floors, vessels, utensils, etc.

Preparation of food (exact details of methods employed, including history and condition of various component parts besides the meat, e.g. pastry, stock and jelly for pork pies, skins of sausages, etc.).

Handling of the food (possible contamination by "carrier" of bacteria associated with food poisoning, (*a*) before cooking, (*b*) during cooking, (*c*) after cooking, e.g. transfer into moulds, etc).

Temperature reached in cooking; any experimental verification of temperature, especially as regards interior of mass; any reason to suspect under-cooking of whole or part.

Cooling. Where food placed during cooling. Possible opportunities of contamination.

Health of workers previous to outbreak, especially in regard to diarrhœa; their habits as to cleanliness. What w.c. accommodation for workers (where situated and condition). Arrangements for washing hands, and their use.

Collection and Examination of Material for Bacteriological Examination

Samples collected (dates, description, and quantities) of:—

Food materials. (*a*) Portions left over by patients, (*b*) obtained at shops, stores, or places of preparation.

Clinical materials. (*a*) Blood from patients or suspected "carriers," (*b*) post-mortem specimens.

Fish

As a rule, fish is nutritious and digestible, but deficient in fat, though eels contain it in abundance, and salmon and herrings also. Fish should be eaten only in season, unbruised, fresh, firm, and free from offensive smell or disease. Unsound fish is dull in appearance, discoloured, and offensive. The least decomposition renders fish unfit for food, and liable to cause gastro-intestinal irritation if eaten. Similar symptoms occasionally follow the use of apparently sound fish. The consumption of halibut, and probably of other fish also, has been known to cause diarrhœa and vomiting, and within a few hours a vivid red rash may appear over the upper part of the body, followed by profuse desquamation lasting several days. Fish is largely preserved by the means already referred to, and especially by drying, curing, salting, or canning.

Oysters and shell-fish.—Oysters eaten raw are readily digested, but other shell-fish are as a rule indigestible and not infrequently cause dyspepsia and urticaria. Mussels are especially prone to be poisonous, the symptoms including not only dyspepsia and urticaria, but also swelling of the tongue and fauces, numbness of the limbs, and weak, irregular pulse. Severe and often fatal attacks have been attributed to eating mussels gathered upon shores polluted by sewage. Many of the cases of mussel-poisoning are believed to be due to simple acute dyspepsia, but others have been traced to an alkaloidal poison (*mytilotoxine*) contained in the liver of the mussel. (*Brieger.*)

Cockles and periwinkles are usually cooked, but mussels are often eaten raw, and, if taken from beds to which sewage has access, appear occasionally to have given rise to enteric fever among consumers.

Oysters, under like conditions, have been found to convey enteric fever, and a number of typhoid and other epidemics have now been traced to their consumption.

In 1896 Bulstrode and Klein reported to the **L.G.B.** upon Oyster Culture in Relation to Disease. Experiments by Klein gave results which are thus summarized by Thorne Thorne in the introduction to this Report:

1. The cholera vibrio, and still more the typhoid bacillus, are difficult of demonstration in sewage known to have received them.
2. Both these organisms may persist in sea-water tanks for two or more weeks, the typhoid bacillus retaining its characteristics unimpaired, while the cholera vibrio tends to lose them.
3. Oysters from sources which appeared to be free from risk of sewage contamination exhibited none of the bacteria, specific or otherwise, which are commonly regarded as being concerned with sewage.
4. Oysters from a few out of numerous batches derived from sources where they did appear to be exposed to risk of sewage contamination were found to exhibit colon bacilli—a circumstance which, notwithstanding the comparative universality of this intestinal organism, may be regarded as having some significance by reason of the absence of this bacillus from oysters which appeared to have been exposed to no such risk.

Since 1894 there have been many considerable outbreaks of enteric fever and gastro-enteritis due to eating infected oysters, including two at Winchester and at Southampton in 1902, which Bulstrode traced to eating oysters grown on beds polluted with sewage. He summarized the evidence as follows: Two mayoral banquets occurred on the same day in separate towns several miles apart. In connexion with each banquet there occurred illness of analogous nature, attacking, approximately, the same percentage of guests (62 persons or 46·3 per cent. at Winchester, 55 persons or 41·3 per cent. at Southampton), and at corresponding intervals. At both banquets not every guest partook of oysters, but all those guests who suffered enteric fever, and approximately all those who suffered other illness, did partake of oysters. Oysters derived directly from the same source constituted the only article of food which was common to the guests attacked, and oysters from this source were at the same time and in other places proving themselves competent causes of enteric fever. Klein found *B. coli*, *B. enteritidis sporogenes*, and other organisms allied to the Gaertner group of bacilli in oysters from the same layings, and many other bacteriologists have demonstrated the presence of these organisms in oysters derived from polluted beds.

The results of the investigations carried out by Houston for the Royal Commission on Sewage Disposal tend to prove that the contamination of oysters by *B. coli* is widespread and not altogether dependent on sewage contamination. He examined over 1,000 oysters, and nearly all, from whatever laying they were taken, contained *B. coli* or coliform organisms. This did not hold good as regards deep-sea oysters, which were free from this organism (and spores of *B. enteritidis sporogenes*), as was also deep-sea water. Houston found the number of *B. coli* in an oyster varied from 10 to 10,000 (in 10–15 c.c.), and the contents of the stomach of the oyster contained more *B. coli* than the liquor in the shell. Fewer *B. coli* were found, as a rule, in oysters stored in pure waters, but instances occurred where the numbers of such bacilli were as great as in oysters from contaminated sources. It has been shown by various workers, in particular by Klein in 1905, that oysters, cockles, and mussels have the power of clearing themselves of infective germs, partly by passing them out, and partly by "directly devitalizing the microbe."

There are certain conclusions which may be drawn. First, the number as well as the presence of *B. coli* in oysters must be considered. Secondly, topographical evidence as to pollution must be taken in conjunction with bacterial evidence, and, at present, the former is more reliable than the latter. Thirdly, oysters ordinarily grown on contaminated oyster-beds may, and do on occasion, contain the virulent specific bacillus of typhoid, which can live both in sea-water and within the shell of the oyster. This being so, the risk of typhoid infection from oysters is a real one, although in actual occurrence many conditions have to be fulfilled.

Other shell-fish than oysters, from time to time, cause epidemics or individual cases of enteric fever, gastro-enteritis, or mytilotoxine poisoning. For the most part the specific contamination of such shell-fish takes place on the beds or layings, in the storage ponds, or in the process of "washing," but occasionally the shell-fish become infected by the retailer (*Bulstrode*).[*] In a report to the **L.G.B.** on "Cockles as Agents of Infectious Diseases," Klein recorded finding *B. coli* and *B. enteritidis sporogenes* in cockles taken from a foreshore polluted with the discharge from a sewer outfall. Similar bacilli were found in cockles bought from a street hawker. In subsequent experiments Klein came to the conclusion that a mussel immersed for 22 hours in cholera-infected water retained the bacilli of cholera for 48 hours after immersion in clean sea-water, and the same may be said in respect of typhoid infection. Indeed, evidence was obtained showing that the typhoid bacillus could multiply in cockles. Merely pouring boiling water over a heap of shell-fish, as is customary, does not necessarily destroy either cholera or typhoid infection contained in them. Prolonged steam sterilization or boiling is necessary. Since the time of Klein's report, a number of outbreaks of disease, including enteric fever, have been traced to the consumption of mussels and cockles, and it has been shown that the cooking which these shell-fish generally undergo is not sufficient to free them from risk.

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[*] *See* Thirty-ninth Ann. Rept. of L.G.B., 1909-10, Special Supplement by H. T. Bulstrode on "Shell Fish other than Oysters in Relation to Disease."

Preventive measures.—Present legislation does not give to local authorities sufficient powers of inspection or control over oyster-layings or shell-fish beds, nor for prevention of the sale in their district of oysters and other molluscs derived from sewage-contaminated sources, nor have they powers to control the importation of foreign oysters from whatever source. Oysters fattened on contaminated beds should be deposited for a time in pure sea-water before consumption. They should on no account be stored in unclean water. The Public Health (Shell-fish) Regulations, 1915, provide for the closure of shell-fish layings which are shown to have caused infectious or other diseases or are believed to be a source of danger to health.

Reports on epidemics due to shell-fish infection should contain (1) a history of the outbreak, (2) details of incidence on consumers and immunity of others, (3) evidence of contamination of layings with sewage, (4) results of bacteriological examination.

MILK

Milk contains nitrogenous substances, fat, carbohydrates, salts, and water, and may be regarded, in a sense, as a complete diet in itself. The chemical composition varies somewhat according to the breed of animal, its age, the period since calving, and the diet and physical conditions.

	Milk of average country-fed cows.	Milk of average town-fed cows.	Alderney milk.	Fore-milk.
Water	88%	86 %	87 %	90 %
Fat	3	4	8·2	0·2
Protein (casein, etc.)	4	5	4·5	9·7
Milk-sugar	4·5	4·3	4·1	
Salts (ash)	0·7	0·7	0·7	0·7

Or the average milk constitution may be expressed thus:—

Fat	4·1 per cent.
Solids not fat	8·8 „
Total solids	12·9 „
Water	87·1 „

Milks vary in standard, and the above figures can only be taken as fair averages.

Milk-sugar, or lactose ($C_{12}H_{24}O_{12}$), is a constant constituent of milk, forms the chief substance in solution in whey or serum, and is a member of the cane-sugar group. It is found in varying quantities in the milk of mammals. About 5 per cent. is present in human milk, and somewhat less in that of the cow. It is very resistant to fermentation by yeast, and therefore undergoes alcoholic fermentation very slowly. It is not acted upon by rennet, pepsin, or trypsin. But of all the sugars it is most readily acted upon by micro-organisms.

Fat occurs in milk as suspended globules of varying size. It forms the cream, and by churning is, of course, made into butter, though both cream and butter contain other constituents besides fat. Lloyd has shown that it is the large globules that form the cream, and he has also made observations upon the size of fat globules in relation to breed of cattle. The decomposition and breaking down of milk-fat by fermentation is the chief cause of gross abnormalities of cream and the rancidity of butter. The proportion of cream averages about 8 per cent., but ranges from 6 per cent. in very poor milk to 12 per cent. or 15 per cent. or more; in Alderney cows it may reach 40 per cent. One part of cream is said to correspond roughly to 0·2 part of fat. More complete separation of cream is effected by centrifugalization in a "separator." Skimmed milk retains, as a rule, about 1 per cent. or more of fat; separated milk much less. Both contain the casein, sugar, and salts of the milk from which they were made, and have therefore considerable nutritive value. "Fore-milk," which is the first part of the yield of milk from the udder, contains but little fat; the "strippings," on the other hand, at the end of milking, are rich in fat.

The **proteins of milk** include casein, lactalbumin, and lacto-globulin. Casein is the most abundant and important. When milk separates naturally into its constituent parts, the fat rises and the casein falls, leaving a clear fluid, the milk plasma or serum, between the two substances.

Mineral matter.—The ash of milk, obtained by careful ignition of the solids, contains calcium, magnesium, potassium, sodium, phosphoric acid, sulphuric acid, chlorine, and iron—phosphoric acid and lime being present in the largest amounts.

Human milk contains less fat, less protein, and more sugar than cow's milk (e.g. an analysis of average human milk would result in total solids, 12·5; fat, 3·7;

proteins, 2·3; lactose, 6·2; and ash, 0·3), and therefore to modify cow's milk so as to bring it approximately to the standard of human milk it is necessary to dilute it and add milk-sugar. Much debate has arisen as to what should be accepted as the minimum standard for the various constituents of milk. Broadly, it is now usual to fix the fat standard at 2·75–3 per cent., and the "solids not fat" at 8·5 per cent.

In 1901 a Departmental Committee recommended (*inter alia*) that regulations should be made under section 4 of the Food and Drugs Act, 1899, for presuming that milk (other than skimmed, separated, or condensed) was deficient in which total solids were below 12 per cent., fat below 3·25 per cent., and "solids not fat" less than 8·5 per cent.

The Sale of Milk Regulations of 1901 which followed this Report lay down that (*a*) where a sample of milk contains less than 3 per cent. of milk-fat, it shall be presumed until the contrary is proved that the milk is not genuine by reason of the abstraction therefrom of milk-fat or the addition thereto of water; (*b*) where a sample of milk contains less than 8·5 per cent. of "solids not fat," it shall be presumed until the contrary is proved that the milk is not genuine by reason of the abstraction therefrom of "solids not fat," or the addition thereto of water; and (*c*) when a sample of skimmed or separated milk (not being condensed milk) contains less than 9 per cent. of solids (including fat), it shall be presumed that the milk is not genuine. These regulations are in force throughout Great Britain.

Adulterations.—Addition of water and abstraction of cream are by far the most frequent frauds. Sodium carbonate, sodium chloride, starch, borax (1–2,000), formalin (1–50,000), or salicylic acid is occasionally added, either as a preservative or in order to mislead the analyst. Skimmed milk or separated milk is frequently fortified by the addition of condensed milk, and whole milk is not infrequently diluted with separated milk. A good deal of "manipulation" of milk goes on, mixing of poor with rich, and of separated and condensed milks with water and with whole milk. Annatto and turmeric are often added to impart a yellow colour to milk.

Addition of water lowers the specific gravity, the percentage of fat, "solids not fat," and salts; it also makes the cream rise more readily to the surface. Abstraction of fat, by skimming or by the use of the separator, increases the specific gravity and the percentage of salts and "solids not fat," but of course reduces the fat and therefore the yield of cream. The addition of condensed milk to skimmed milk may give an appearance of extreme richness, but the salts and "solids not fat" will be in excess.

Owing to the social changes by which an increasing percentage of the population lives in towns, the practice of adding preservatives to milk, with a view to "keeping" it over the necessary transit and delay in reaching the consumer, is increasing.

In 1901 another Departmental Committee appointed by the Board of Agriculture recommended:—

1. That the use of formaldehyde in food and drink be absolutely prohibited, and that salicylic acid be not used in greater proportion than one grain per pint or pound respectively for liquid or solid food, its presence in all cases to be declared.

2. That the use of any preservatives or colouring matters in milk be made an offence under the Sale of Food and Drugs Acts.

3. That only boric-acid preservatives be allowed in cream, the amount not to exceed 0·25 per cent., and to be notified on a label.

4. That only boric-acid preservatives be allowed in butter, the amount not to exceed 0·5 per cent.

5. That chemical preservatives be prohibited in all dietetic preparations for the use of children and invalids.

6. That the use of copper salts for "greening" be prohibited.

7. That a Court of Reference be established to supervise the use of preservatives and colouring matters in food.

In 1912 the **L.G.B.** issued "The Public Health (Milk and Cream) Regulations, 1912," made under the Public Health (Regulations as to Food) Act, 1907. The Regulations secure that no preservative shall be added to milk, or to cream containing less than 35 per cent. by weight of milk-fat, at any stage from the place of production to that of delivery to the purchaser. In the case of cream containing over 35 per cent. of milk-fat, the addition of boric acid, borax, or a mixture of these preservative substances, or of hydrogen peroxide, is not prohibited by the Regulations, but is subject to a system of declaration which is required to be followed by all persons dealing with such cream for the purpose of sale for human consumption. By this system it is intended that preserved cream as an article of commerce shall in all stages be differentiated from cream to which no preservative has been added. Further, the addition of any thickening substance to cream or preserved cream is prohibited. Except as regards Part III. of the Regulations (dealing with restrictions on importation) the duty of administration was placed upon those Authorities in England and Wales which are local Authorities under the Sale of Food and Drugs Acts. By an amending Order, 1917, a "declaratory label" is prescribed stating the presence of preservative and its amount in cream. Boric acid is restricted to 0·4 per cent.

Enzymes and cellular elements in milk.—In addition to its chemical constitution milk possesses certain biological characters. The enzymes or **ferments** belong to two groups—those acting on foodstuffs present in milk, thus aiding its digestion (proteolytic, lipolytic, and lactase), and those which are oxidizing and reducing in function (peroxidase, amylase, and catalase). The cellular elements are (*a*) large uninucleated cells, (*b*) multinucleated cells, and (*c*) small uninucleated cells. Milk may also contain pus cells, blood corpuscles, and leucocytes. A high cell-content, especially if accompanied by streptococci, should be regarded with suspicion.

Bacteria in milk.—Milk as it leaves the healthy udder is a sterile fluid, but at the time of milking, during transit to the dairy, at the milkshop, and in the home of the consumer it becomes more or less contaminated. Being a favourable medium for the growth of bacteria, and being frequently kept for some time at a favourable temperature for the multiplication of germs, milk becomes, as a rule, heavily impregnated with bacteria. In addition to uncleanliness generally, disease of the cow's udder may add tubercle bacilli streptococci, or staphylococci; and infection from those handling the milk may add a further quota. Thus it comes about that milk is often found to contain millions of bacteria per cubic centimetre, varying in number according to cleanliness or otherwise, treatment, temperature, and storage. The species of bacteria found in milk may be roughly classified as: (*a*) ordinary bacteria of soil and water; (*b*) acid-fast bacilli, e.g. butter bacillus, timothy-grass bacillus, and mist bacillus; (*c*) bacteria of sewage, manure, or intestinal origin, particularly staphylococci, streptococci, *B. coli* and allied organisms; (*d*) bacteria of milk fermentation; and (*e*) pathogenic organisms associated with tuberculosis, enteric fever, scarlet fever, diphtheria, sore throat, and epidemic diarrhœa. Here it is only necessary to consider the last two groups of bacteria.

Milk-sugar undergoes fermentation like other sugars upon the introduction of a suitable fermenting agent. There are five different kinds of such fermentation which affect milk, namely, lactic-acid and butyric-acid fermentations, coagulation fermentation without acid-production, alcoholic fermentation, and, lastly, a group of anomalous changes of various kinds. **Lactic-acid fermentation** is the ordinary souring of milk. The coagulated casein is precipitated, the serum rises and carries up lumps of fat, and the whole becomes acid. This change is due to a group of bacilli (*B. acidi lactici*), the first member of which was discovered by Pasteur and isolated by Lister.

They gain access to milk from external sources, particular kinds being found in the vicinity of particular dairies, soils, geographical localities, etc., thus giving to milk and butter characteristic flavours.

The lactic-fermentation bacteria are short rods. They produce appreciable amounts of lactic acid only at somewhat elevated temperatures. If the amount of acid rises much above 2 per cent., the growth of the lactic-acid bacteria is inhibited. Many other substances are produced in addition to lactic acid (e.g. acetic and formic acids, alcohol, methane, CO_2). The most common members of the group are the facultative anaerobes which sour milk best in deep vessels, and produce a right-handed lactic acid. They are widely distributed in nature, and may form 90 per cent. of the total bacteria in milk.

Butyric-acid fermentation, due to the *B. butyricus*, is a bitter fermentation in which hydrogen and carbonic-acid gas are produced. It has little of the importance of lactic fermentation or even of alcoholic fermentation by yeasts, by which "koumiss" is prepared from mare's milk and "kephir" from the milk of goats, sheep, and cows. Other fermentations of milk are represented in (*a*) bitter fermentations (due to Weigmann's bacillus or Conn's micrococcus); (*b*) slimy fermentations which produce the "ropiness" used in the manufacture of Edam cheese and tœttmœlk (due to *Micrococcus viscosus* and *Streptococcus hollandicus*, etc.); (*c*) soapy milk caused by *B. lactis saponacei*, and (*d*) a number of chromogenic fermentations.[*]

Pathogenic organisms gain access to milk both from the cow and from sources external to milk. The *tubercle bacillus* is the chief example of the former channel. Probably not less than 10 to 15 per cent. of the milch cows of this country are affected with tuberculosis, and about 2 per cent. with tuberculous disease of the udder.[*] The milk is most infective when the udder is diseased. Bovine bacilli may, however, be present in the milk of tuberculous cows presenting no evidence whatever of disease of the udder, even when examined post mortem. Tubercle bacilli in milk may also be derived from excreta or uterine discharges of tuberculous cows. Bovine tubercle bacilli may be the cause of abdominal and cervical-gland tuberculosis in children consuming the milk.[†] From 1897 to 1908 it was found that 8·7 per cent. of the country-mixed milk (railway samples) brought into Manchester was tuberculous, and percentages varying from 5 to 16 have been frequently reported in market milk in this country. In 1911 it was officially reported that of 5,698 samples of milk taken at the London railway termini since the London County Council (General Powers) Act, 1907, came into operation, 11·2 per cent. proved to be tuberculous. Whilst tuberculosis is not commonly spread among human beings by means of an infected milk supply, there is evidence, derived from pathological and clinical experience, proving that tuberculous milk can and does, on occasion, set up some form of tuberculosis, human or bovine, in the bodies of man and other animals consuming the milk. Phthisical milkmen may introduce the human tubercle bacillus into milk. All danger may be obviated by boiling the milk. The *typhoid bacillus* has occasionally found its way from sewage, water, or infective dust into milk, which is a favourable medium for its multiplication. The same may be said of the *diphtheria bacillus*, which, in several cases on record, has been isolated from milk suspected of conveying the disease (*Bowhill, Eyre, Klein, Dean and Todd*). Some authorities now hold that diphtheria is a disease of the cow and that the bacillus sometimes gains access to milk from the udder. Various forms of streptococcus have also been isolated from milk. Their exact pathological significance is not yet determined.

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[*] Red milk (*B. prodigiosus* and *B. lactis erythrogenes*); blue milk (*B. cyanogenes*); yellow milk (*B. synxanthus*); etc.

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[*] There are about 4,000,000 milch cows in the United Kingdom. A cow yields on an average about 400–500 gallons of milk per annum.

[†] Final Report of Royal Commission on Tuberculosis (Human and Bovine), 1911, Part I., p. 40.

Examination of milk.—1. **Specific gravity** of milk is measured by a lactometer (which is a delicate hydrometer) or by a Westphal balance. The specific gravity averages about 1030–1032. It is lowered by watering, and raised by abstraction of fat.

2. **Total solids,** which range from 12 to 13 per cent., are estimated by evaporating a small quantity of the milk in a platinum dish, weighing before and after drying (weight of residue × 100 divided by weight of milk = percentage total solids). By deducting the amount of fat, the solids not fat are obtained. The ash of milk, usually about 0·7 per cent., is of little value as an indication of quality.

3. **Fat** may be determined (*a*) by mechanical methods such as centrifugalization, or (*b*) by extraction of the fat by ether, with or without preliminary destruction of the casein by acid. In Adams's method 5 c.c. of the milk are spotted on to a porous paper, which is thoroughly dried, and then rolled up and extracted with ether in a Soxhlet apparatus. The ether is siphoned off and evaporated, and when a constant weight is obtained the quantity of fat is determined. Werner-Schmidt's method is extraction of fat with ether, after destruction of casein with strong hydrochloric acid.

The fat in unadulterated milk is never less than 3·0 per cent., unless the "fore-milk" alone is taken, so that, when skimming as well as watering is suspected, the ratio 3·0 : 8·5 may be taken as the minimum proportion of fat to "solids not fat," and if the "solids not fat" are x, the fat should be *at least* $\frac{3\cdot0}{8\cdot5}x$; and if the ascertained amount y of fat falls short of this, it is concluded that at least $100 \times \left(\frac{3\cdot0}{8\cdot5}x - y\right) \div \frac{3\cdot0}{8\cdot5}x$ per cent. of fat has been abstracted.

4. **Water.**—The results of many thousands of analyses show that, although the fat varies greatly, the percentage of "solids not fat" in unadulterated milk falls below 8·5 very

rarely. Hence 8·5 per cent. is adopted as a standard. If a given milk contains x per cent. "solids not fat," and x is less than 8·5, we can affirm that, however poor the milk might have been originally, it must contain added water to the extent of at least $\left(\frac{8{\cdot}5 - x}{8{\cdot}5} \times 100\right)$ per cent. of the sample; or, in other words, it is $\left(\frac{8{\cdot}5 - x}{8{\cdot}5} \times 100\right)$ per cent. worse than genuine milk of poorest quality. If it was originally milk of fair quality, the adulteration must have been much greater.

5. **Preservatives in milk.**—*Boric acid* is detected by moistening the ash with alcohol and H_2SO_4, and applying a light to the mixture, when so little as 1 part in 10,000 will give a green flame; or the ash may be treated with dilute HCl, and turmeric paper will be turned brown, and, if touched with sodium carbonate, bluish-black. *Salicylic acid* is detected by curdling the milk with mercuric nitrate, and then, after shaking it up with ether, evaporating, and moistening the residue with ferric chloride. A blue coloration will denote the presence of salicylic acid. *Formalin* in milk gives a purple colour if warmed with hydrochloric acid containing a trace of iron.

6. **Bacteriological examination** is somewhat similar to that of water. Its objects are (*a*) to determine presence and degree of external contamination, (*b*) to detect presence of pathogenic germs, (*c*) to obtain evidence as to health of cow's udder. Plate cultivations are made, etc., but it is necessary to dilute the milk with sterile water (decimal dilution method). Special methods of examination have to be adopted in searching for pathogenic organisms. Generally it may be said that by the centrifuge or sedimentation flask the particulate matter is obtained and examined, and 2 c.c. are inoculated into a susceptible animal. For reliable examination for the tubercle bacillus it is necessary to inoculate animals with the milk, as many bacilli simulate the tubercle bacillus in almost every particular, except its pathogenic effect. Special staining and culture tests are necessary for *B. diphtheriæ*, streptococcus, *B. coli*, and *B. enteritidis sporogenes*. The laboratory examination of milk should include (1) the number and kind of bacteria present; (2) the degree of acidity; (3) the presence or absence of pus or blood cells, yeast cells, dirt; (4) the estimation of *B. coli* and allied lactose fermenters; (5) estimation of spores of *B. enteritidis sporogenes* and presence of streptococci; (6) the examination of the stained deposit.

Milk in relation to disease.—From the point of view of preventive medicine the chief milk-borne zymotic diseases are enteric fever, diphtheria, scarlet fever, sore-throat illnesses, and epidemic diarrhœa. Probably tuberculosis is not commonly spread by milk, though undoubtedly milk does serve as a means of infection, especially in children. Indeed, the Royal Commission on Tuberculosis (1911) concluded that a considerable amount of the tuberculosis of childhood is to be ascribed to infection with bacilli of the bovine type transmitted to children in meals consisting largely of cow's milk. In England and Wales, in 1915 upwards of 7,000 children under 15 years of age died of tuberculosis (excluding phthisis, lupus, and scrofula). Whether other infectious diseases, such as measles, whooping-cough, and small-pox, are ever conveyed by milk remains to be proved.

Diseases of the cow affecting the milk may be general or local. Anthrax, gastro-enteritis, and septic conditions are types of the first group; acute mastitis, foot-and-mouth disease, ulcerated teats, actinomycosis of the udder, suppuration of the udder, and "Hendon disease" (*see* p. 143) of the second. An inflammatory affection of the cow's udder, known as **garget** or **mastitis**, has been suspected of causing outbreaks of sore throat, etc., in those using the milk. It is commonly caused by streptococci or staphylococci, which are probably not directly virulent to man, though no doubt virulent types exist (*Savage*). Milk from cows suffering from foot-and-mouth disease is capable of producing illness with aphthous stomatitis, swelling of the tongue, and fetor of the breath, especially in children; in other cases a severe form of sore throat has been the chief feature. Similar symptoms may attend the consumption of milk from cows affected with inflammation or abscess of the udder. The evidence is less clear in regard to other specific diseases to which cows are subject, and, indeed, in most of them the secretion is suppressed, but the milk should never be used for food. In 1913 a serious outbreak of gastro-intestinal disease occurred at Newcastle-upon-Tyne, affecting 523 persons. The origin was shown to be septicæmia of the cow. In the Western States of America cows are subject to a disease called the "trembles," supposed to be due to their eating *Rhus toxicodendron*, and their milk appears to cause in children vomiting, constipation, swelling of the tongue, and prostration, with abnormally low temperature. The milk of goats that had fed on *Euphorbium*, or meadow saffron, has been known to induce severe diarrhœa. Even in the human subject bitter and purgative drugs, not to mention morphia and other alkaloids, if taken by the mother, act upon the infant through the milk. Colostrum, the milk yielded by cows immediately after calving, has also been shown to exert a deleterious effect on persons consuming it. Lastly, disease has been caused, it is believed, by pathogenic yeast-cells in milk. Such an outbreak occurred at Lincoln in 1902 (199 cases). The symptoms of the disease simulated scarlet fever. There was much swelling of the tonsils and cervical glands, with pyrexia, gastritis, and "rheumatism." Klein isolated what he believes to be a pathogenic yeast possibly bearing a relationship to the spores of teats, smuts, and mushroom fungi consumed by the cows yielding the milk.

Enteric fever.—In 1857 Michael Taylor, of Penrith, first established the fact that milk may convey enteric fever. Since that date more than 150 epidemics of this disease have been traced to an infected milk supply. Schuder states that 17 per cent. of all typhoid epidemics are thus caused. The channels of infection by which the bacillus obtains access to milk have been shown by a study of these outbreaks to be from direct contact with typhoid patients (or typhoid "carriers"), from washing milk-vessels with infected water, from the addition of such water to the milk, from the air by dried typhoid excreta, from contaminated cloths and clothes, and from cooling milk in infected water. In one case (1909) it was shown that milk had become infected by a milkman who was a "typhoid-carrier," and during 17 years 230 cases of enteric fever occurred among persons who obtained milk from a farm on which this milkman was employed. A milk-borne outbreak in Dublin in 1908 affecting 130 persons was likewise traced to a "carrier" case.

Cholera.—Numerous cases have been recorded in which cholera has been transmitted by means of infected milk. A sharp outbreak of such milk-borne cholera occurred in Bengal in 1909. Investigation showed that the outbreak was due to the handling of milk by native servants whose hands were found to be infected with cholera organisms. One of the men, though in good health, was found to be a chronic "carrier" of cholera infection.

Diphtheria.—The first epidemic of diphtheria which was shown to be milk-borne was one in North London in 1878, elucidated by Power. More than 30 similarly caused outbreaks of the disease have since been recorded. How the diphtheria bacillus gains access to milk is not known, but in all probability it is generally by direct human contact. Persons suffering from the disease may remain for a long period infectious by reason of the retention for weeks after convalescence of the bacillus in the throat. Materials may also retain the infection for long periods. Water and sewage do not appear to convey the diphtheria bacillus. Klein holds that the Klebs-Löffler bacillus is inoculable in cows, producing a specific eruption on the udder, and within five days the bacillus is excreted in the cow's milk. Several outbreaks of diphtheria have suggested that bovine diphtheria is transmissible to man by milk, but though on two or three occasions diphtheria bacilli have, in fact, been isolated from lesions of the udder, the existence of natural bovine diphtheria has not been proved.

Scarlet fever.—More than 100 milk-borne attacks of scarlet fever are on record, and yet comparatively little is known either of the bacteriology of the disease or of the mode of infection of milk. Direct contact of scarlet-fever patients with the milk trade is the most obvious channel of infection. In 1882 Power found reason to suspect that cows suffered from a disease which could impart to milk the virus of scarlet fever, and in 1885 in the "Hendon disease" outbreak further evidence of this was met with.

In that year a sudden and extensive outbreak of scarlet fever occurred in Marylebone, and was found to be associated with a particular milk supply derived from a farm at Hendon. The milk was also distributed in St. Pancras, Hampstead, Hendon, and St. John's Wood; in each of these districts, except the last, scarlet fever suddenly became prevalent early in December. On the 15th the milk sent to Marylebone was returned to the farmer, and some of this was given away to persons at Hendon on the 15th and 16th; a few days later, from December 20th onwards, a number of cases of scarlet fever occurred among those who had drunk the milk, and at the same time there was a sudden decrease in the number of attacks in Marylebone. The disease was conveyed by the milk, and after close investigation Power and Klein were led to the important conclusion that the cow itself was the source of infection.

There had been apparently no case of scarlet fever among the employees that could be proved to have infected the milk. Attention was next directed to the cows, and many of them were found to be suffering, or to have recently suffered, from vesicles or ulcers upon the teats and udder. These were clearly infectious, and had been first seen upon a cow that was bought on November 15th. The dates of outbreak of scarlet fever in each district being known, it was found that each outbreak was preceded by a few days by the introduction of this affection into the cowsheds from which the milk supply of the district was drawn. The early exemption of St. John's

Wood was explained by the fact that the disease had not appeared in the small shed from which alone its supply was drawn: but during the inquiry this shed became affected at last, and an outbreak in St. John's Wood immediately followed. All the cows showing any signs of the disease were then isolated, and no further cases of scarlet fever occurred among the consumers of the milk. The symptoms noticed in the cow were chiefly local, but there were bald patches of skin, especially about the tail and back, the epidermis in these patches being scaly and the cutis thickened. There was no pyrexia. The vesicles, which were small, were confined to the teats and udder. They extended, and in two days formed flat irregular ulcers covered with brown scabs. Inoculated upon calves, the matter from these ulcers caused local tenderness and swelling in three days, a scabbed ulcer with vesicular margin in six days, and a further extension during the next few days, followed by healing. By cultivation a streptococcus was obtained, supposed to be identical with a similar organism found by Klein in connexion with scarlet fever, and having the property of solidifying milk if kept for two days at 35° C. It was not found in the milk from unaffected teats. Inoculation of calves with pure cultivations of the streptococcus produced a constitutional disease that had some points of analogy with scarlet fever, the condition of the kidneys especially differing but little from acute scarlatinal nephritis.

In 1889 a milk-borne outbreak of scarlet fever in Glasgow was traced to a micrococcal infection of the cow's udder; and in 1903 there was an outbreak of "Hendon disease" at Lincoln. In June 1909, a widespread epidemic of scarlet fever occurred in South-West London, traced to a farm in Wiltshire where a number of the cows were found to have sores and scabs on the teats. From material taken from three affected teats Gordon isolated two types of streptococcus, one resembling *S. anginosus* (Andrewes) and the other *S. mastitidis* (Savage) of garget.

Sore-throat illnesses.—Somewhat allied to scarlet fever, and possibly in some instances an aberrant form of that disease, is sore-throat infection conveyed by milk. There are fully a score of well-marked epidemics of this nature on record. One of the first to be investigated occurred in South Kensington in 1875. About 150 persons were affected after consuming cream. A similar outbreak occurred in Edinburgh in 1888. More recent outbreaks of milk-borne sore-throat occurred at Bedford in 1902, Guildford 1903, Finchley 1904, and Colchester 1905. Cream was again the particular medium at Bedford, where the incidence was chiefly upon young adults. In the Guildford outbreak 98 families were affected, and the milk was traced to cows suffering from *suppurative mastitis*. The Finchley outbreak involved 500 cases. The incubation period, as in many of these sore-throat conditions, was short –24 to 48 hours. There were enlargement of the submaxillary glands, sore throat, fever, general malaise, and in a few cases a measles-like eruption on the lower limbs. On some occasions gastro-intestinal irritation has also been present. It is possible that these sore-throat illnesses are of streptococcal origin.

In many milk-borne outbreaks of scarlet fever there occur a number of sore-throat cases simulating, but possibly not identical with, scarlet fever, in addition to those which are milder forms of scarlet fever itself.

Epidemic diarrhœa is another infective disease which appears to be conveyed by milk. Certain attacks of the disease give support to this view, and there is also the autumnal rise of infantile diarrhœa, which is attributed by many observers, in part, to contaminated milk. It is held that the high atmospheric temperature of the third quarter of the year exerts a prejudicial effect on milk, causing it to be injurious, particularly to infants and children. It is certain that breast-fed infants suffer much less than artificially fed infants from such disease. Actual epidemics of milk-borne diarrhœa have been, it appears, comparatively few. In 1894 such an outbreak occurred in Manchester, affecting 160 persons, and due probably to milk polluted with excreta; in 1895 and 1898 three outbreaks occurred at St. Bartholomew's Hospital, traced to the consumption of milk or milkpudding from which Klein isolated the *B. enteritidis sporogenes,* which he regards as the *vera causa* of epidemic diarrhœa; and in 1908 there was an outbreak of milk-borne gastro-enteritis at Aberdeen (70 cases).

Characteristics of milk-borne epidemics.—There are certain general characteristics of outbreaks of disease transmitted by milk which it may be well briefly to state here.

1. The outbreak is usually sudden in onset; and the cessation often almost equally so, if allowance is made for secondary cases in infected households, which have probably been infected from the earlier cases and not by the milk.

2. A large proportion of the attacks are simultaneous or nearly so. The outbreak reaches its maximum too rapidly to admit of satisfactory explanation by the hypothesis of infection from the first cases; thus, in an outbreak of scarlet fever at Wimbledon in 1886–7, the daily number of attacks was as follows:—

Date . .	Dec. 25	26	27	28	29	30	31	Jan. 1	2	3
Attacks .	1	11	39	53	75	118	65	86	25	15

3. It will often happen that two or more persons in the same household are taken ill at the same time. Such multiple cases may also occur apart from milk or water infection, but it is very exceptional, especially as regards the first invasion of the household.

4. The average number of cases per infected household is usually greater than occurs under ordinary conditions, but this is, of course, dependent upon the number of persons who consume the milk. An *average* of two attacks per household may be considered high.

5. A large proportion of the households attacked

have a common milk supply, which, however, may not be distributed by the same retailer.

6. Conversely, if (*a*) the number of households supplied by the suspected dairy be ascertained, and also (*b*) the number of such households attacked, it will be found that the proportion of (*b*) to (*a*) is much greater than the proportion which the total number of infected households bears to the total number of inhabited houses in the district. Although in some cases 50 per cent. or more of the houses supplied with the implicated milk are attacked, in other instances the proportion is far lower.

7. If the households supplied by the dairy in question are classified according to the quantity of

STATISTICS OF THE WIMBLEDON OUTBREAK ILLUSTRATING THE RELATIONS SET OUT IN PARAGRAPHS 3-8 (*Cooper*).

Incidence on consumers, according to supply per head.		Incidence on houses, according to supply per house.		Incidence on houses, according to rental.	
Pints.	Percentage of persons supplied attacked.	Pints.	Percentage of houses supplied invaded.	Rateable value of houses supplied.	Percentage of houses supplied invaded.
0·05 to ·1	14	0·25	40	£10 to £12	21
0·1 to ·2	23	0·5	40	£13 to £15	39
0·2 to ·3	41	0·75	50	£16 to £20	50
0·3 to ·4	39	1·0	49	£21 to £25	64
0·4 to ·5	46	1·5	58	£26 to £30	66
0·5 to ·6	57	2·0	70	£31 to £35	57
0·6 to ·7	40	3·0	67	£36 to £40	76
0·7 to ·8	46	3·5	74	£41 to £50	73
Over 0·8	49	Over 3·5	78	£51 to £60	74
				£61 upwards	80

milk bought daily, the invasions are found to be proportionately more numerous among households taking a larger supply.

8. A similar calculation, substituting individuals for households, will give similar results. Classifying the consumers according to the average consumption per head in the households to which they belong, a heavier incidence upon the larger consumers will be manifest. Hence the wealthier consumers, upon the average, suffer more than the poorer class in milk-borne outbreaks, and a classification according to rental will usually confirm this.

9. Among persons who drink little or no milk, or only take it in tea or coffee, or always have it boiled, attacks will be rare, except after exposure to infection from earlier cases.

10. As a corollary to this, there is often a much heavier incidence among children and women than among men. This would be especially significant in regard to enteric fever, which under ordinary conditions chiefly affects adults. On the other hand, Littlejohn has pointed out that in milk-borne scarlet fever an exceptionally high proportion of adults may suffer.

11. The type of disease in milk-borne epidemics has been noticed to be, as a rule, mild, and attended with low mortality.

12. The incubation period is shortened, and there is some reason to suppose that the degree of infectiousness by contact is lower than when such diseases are not milk-borne.

Ice-cream or iced custards, which have as their basis milk or cream mixed with other ingredients, may be briefly considered here in their relation to infection. A number of outbreaks of typhoid or diarrhœal disease have been attributed to the consumption of ice-cream. Such outbreaks occurred at Deptford (1891), Liverpool (1897), City of London and Finsbury (1902), Paisley (1904), and Eccles (1910). The ice-cream may become infected owing to storage in infected premises, between the process of "boiling" and that of "freezing," or owing to the fact that the substance has been made by a person suffering from recognized or unrecognized disease. It is on this account that, since 1895, local regulations have been in force with the view of controlling the manufacture of ice-cream. Under the London County Council (General Powers) Act, 1902, ice-cream must be made and stored in sanitary premises, not living-rooms, precautions must be taken as to protection from contamination, and the name and address of the maker must appear on the street-barrows. Similar powers are conferred by local Acts in Liverpool, Glasgow, etc.

Control of milk supplies.—The requirement is a pure milk supply, or in other words a clean, whole milk, unsophisticated and unadulterated, (*a*) derived from healthy cows, guaranteed free from tuberculosis by the tuberculin test, and living under clean and sanitary conditions; (*b*) obtained by clean methods of milking, strained, and protected from contamination and from infection; (*c*) kept cool by means of refrigeration; and (*d*) not exposed to dust or uncleanliness in any way from the cow, the milker, from the vessel in which it is placed, or from the persons by whom it is handled.

There are four means by which control can be exercised: (i.) the *consumer* can demand pure milk and can keep it clean and sweet or boil it; (ii.) the *dairy trade* can conduct its business on sanitary lines; (iii.) *communal enterprise*, by medical commissions or otherwise, can produce "certified" milk of standard quality; and (iv.) the *Sanitary Authority* can exert legal control of the milk supply (*see* pp. 595, 607, 616, 627, 630, 648) in regard to adulteration, cleanliness, and infection.

Control by the dairy trader begins with the health and veterinary management of the cow, improved byres, clean cows, and clean milking (milkers and vessels). Subsequent protection with effective straining and cooling is also necessary (including rapid transit to market). Low temperatures do not readily destroy germ life, but they have a most beneficial effect upon the keeping quality of milk. If the temperature be lowered sufficiently, the contained bacteria become inactive and torpid, and eventually are unable to multiply or produce their characteristic fermentations. At about 50° F. (10° C.) the activity ceases, and at a temperature of about 40° F. organisms are practically deprived of their injurious powers. If the milk is to be conveyed long distances, then even a lower temperature is desirable. The most important point with regard to the cooling of milk is that it should take place *immediately*. Various kinds of apparatus are effective in accomplishing this. Perhaps those best known are Lawrence's and Pfeiffer's coolers, the advantage of the latter being that during the process the milk is not exposed to the air. It must not be forgotten that cooling processes are not sterilizing processes, and do not necessarily kill bacteria; they only inhibit activity, and under favourable circumstances torpid pathogenic-bacteria may again acquire their injurious faculties. Hence, during the cooling of milk even greater care must be taken to prevent aerial contamination than is necessary during the process of sterilizing milk. No cooling should be attempted in the cowshed. Climate makes little or no difference to the practical desirability of cooling milk, yet it is obvious that less cooling will be required in the cold season. The further treatment of milk has in practice comprised the addition of *preservatives*, *condensation*, and *sterilization*, but with first-rate clean milk, consumed or bottled immediately after yield, these are not necessary.

Preservation of milk may be effected by boiling, by exclusion of air, or by the addition of sugar, borax (1–2,000), formalin (1–50,000), or other antiseptic. Such preservatives are frequently added to milk, especially in towns. They prevent rapid multiplication of germs, and so delay or prevent fermentation. On the other hand, they disguise the true condition of the milk, and by cumulative process may cause poisoning in the consumers, and therefore should be condemned. In ordinary circumstances, with clean dairying and effectual cooling, preservatives are wholly unnecessary. The **L.G.B.** (1906) advise taking action if boron preservatives are present in amount exceeding 40 grains per gallon.

Condensed milk is prepared by evaporating down *in vacuo* at a low temperature to about one-third or one-quarter of the original volume, and most manufacturers then add cane sugar as a preservative. The added sugar renders it too carbonaceous and "fattening," though lacking in fat, but apart from this the nutritive value of condensed milk seems to be inferior to that of fresh milk, especially in regard to bone-formation and stamina. Condensed milk is, as a rule, fairly free from suspicion of ordinary adulteration or pollution, but it is by no means always sterile. It is placed on the market as sweetened or unsweetened condensed whole or separated milk. Its indiscriminate use is open to objection, and its sale calls for strict control. *Dried milk* is now widely used. It is the powder obtained by passing milk rapidly between heated surfaces, or by drying on a cylinder in partial vacuum. It is used mixed with water. It lacks enzymes, but is nutritious.

Sterilization means the use of heat at or above boiling-point, or boiling under pressure. This may be applied in one spell of one to two hours at 212–250° F., or at stated intervals at a lower temperature. The milk is sterilized—that is to say, contains no living germs—is altered in chemical composition, and possesses a flavour which to many people is unpalatable.

Such a radical alteration is not necessary in order to secure non-infective milk. The bacteria causing the diseases conveyable by milk succumb at much lower temperatures than the boiling-point. Advantage is taken of this in the process known as **pasteurization**, in which milk is heated to 167–185° F. (75–85° C.). Such a temperature kills harmful microbes, because 75° C. is above their average thermal death-point, and yet the physical changes in the milk are practically nil, because 85° C. does not relatively approach the boiling-point. There is no fixed standard for pasteurization, except that it must be above the thermal death-point and below the boiling-point. As a matter of fact, 158° F. (70° C.) will kill lactic-acid bacteria and most disease-producing organisms found in milk. If milk is kept at that temperature for ten or fifteen minutes, it has been "pasteurized." If it has been boiled, with or without pressure, for half an hour, it has been "sterilized." The only practical difference in the result is that sterilized milks have a better keeping quality than pasteurized, for the simple reason that in the latter some living germs have been unaffected.

Sterilization may, of course, be carried out in a variety of modifications of the two chief ways above named. When the process is to be completed in one event an *autoclave* is used, in order to obtain increased pressure and a higher temperature. Milk so treated is physically changed in greater degree than in the slower process. The slow or *intermittent* method is, of course, based on Tyndall's discovery that actively growing bacteria are more easily killed than their spores. The first sterilization kills the bacteria, but leaves their spores. By the time of the second application the spores have developed into bacteria, which in turn are killed before they can sporulate. Electricity has been used in sterilizing milk, with good results.

The application of pasteurization to milk is now very widely adopted by corporations, dairy companies, hospitals, milk-dispensaries, etc.

BUTTER

When cream is violently agitated, the fat globules are ruptured and their contents clot together as butter. The water is expelled by pressure, and salt is added. The flavour of butter is due to the butyrin, caproin, and caprylin, which together constitute about 7·8 per cent. of the fat, the rest being composed of olein, stearin, and palmitin. Besides fat, which constitutes about 85 per cent., butter contains water, casein, and salts. The casein averages 2·5 per cent., but may reach 7 per cent. if the butter is carelessly made; such a butter keeps badly. The water ranges from 8 to 12 per cent. in good butter, and should never exceed 16 per cent. "Milk-blended" butters have been found to contain nearly double this amount of water. The ash should not exceed 8 per cent.; in pure fresh butter it is usually about 2 or 3 per cent. or less, and includes calcium phosphate and sodium chloride.

Adulterations and analysis.—The addition of annatto or other harmless colouring matter is not regarded as adulteration. Starch is sometimes added, and may be recognized by its blue reaction with iodine. The chief and only important adulterations practised are the substitution of foreign fat and the addition of water or preservatives, and, therefore, the analysis of butter turns chiefly upon the proportion and composition of the fat and the proportion of water.

1. The fat should exceed 80 per cent. of the whole. (If the butter is melted in a tall glass, the water and curd will collect at the bottom, leaving the pure fat above.)

2. The specific gravity of pure butter-fat should range from 911 to 913. Margarine examined under similar conditions would range from 901 to 906.

3. The melting-point of the fat should be about 35·8° C., but it is liable to variation, not only with variation in the relative proportions of normal constituent fats, but also with

repeated meltings. Adulteration with dripping, lard, or other animal fat raises the melting-point, while vegetable fats lower it.

4. The soluble fatty acids (butyric, caproic, caprylic) should not be less than 5 per cent. of the fat, and the insoluble fatty acids should not exceed 89·5 per cent. Butter fat differs from all others in containing fatty acids that are soluble in water, and their partial or complete absence denotes substitution of foreign fat.

5. Pure butter-fat is readily soluble in ether, whereas other fats dissolve slowly and leave a residue.

6. Fat crystals may be visible under the microscope, and serve to show that the butter has been melted, presumably for the purpose of adulteration.

7. Water is estimated by heating a weighed quantity of butter over a water-bath until it ceases to lose weight.

The Regulations for the sale of butter, made in 1902 by the Board of Agriculture under section 4 of the Sale of Food and Drugs Act, 1899, provide that "where the proportion of water in a sample of butter exceeds 16 per cent. it shall be presumed for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the butter is not genuine by reason of the excessive amount of water therein."

Nothing has been made out very clearly as to the convection of specific disease by means of butter. An outbreak of diarrhœa in a large hospital was shown by Sir Shirley Murphy to be in all probability due to the consumption of a particular kind of butter. The symptoms resembled those of tyro-toxicon poisoning, to be mentioned presently (p. 156).

Margarine has been the subject of special legislation (the Margarine Act, 1887, and the Sale of Food and Drugs Act, 1899), which will be referred to in another section. The term is applied generically to fats of either animal or vegetable origin, the former prepared by churning melted and clarified beef or mutton fat with skim milk, and so treating it as to resemble butter in appearance and flavour as far as possible. For this purpose a certain proportion of genuine butter is frequently mixed with margarine. It may possess nutritive value little inferior to butter, especially if manufactured from pure animal fats. Chemically it differs from butter in containing only traces of "soluble" fatty acids. It consists mainly of olein, stearin, and palmitin. The absence of butyrin, a chief constituent of butter fat, is the most valuable means of distinguishing between butter and margarine.

CHEESE

Cheese is formed by the action of rennet upon milk, and consists of coagulated casein with a variable proportion of fat and salts. The best, such as Cheddar, Cheshire, double Gloucester, and most American cheeses, are made from entire milk, the poorer from skim milk, or a mixture of skim and entire milk. Stilton cheese is made from entire milk to which cream has been added. Cheeses vary widely as to the amount of fat and water which they contain. A good cheese, if kept under suitable conditions of temperature, undergoes a change, known as "ripening," which improves its flavour. Oxygen is absorbed, ammonia and carbonic acid are given off. The casein undergoes fatty metamorphosis, and the calcium phosphate reacts upon the fats and the casein, giving rise to lime salts of fatty acids, and a soluble compound of casein with phosphoric acid. Lactic acid, valerianic acid, and leucin are also formed. Both in cheese- and butter-making this ripening process is due to bacteria and their products, and it is on account of this fact that much has been done in Denmark and America in the way of flavouring butter and cheese by introducing favourable organisms as "starters" of the desired fermentation. Both natural and artificial ripening occasionally go wrong, and as a result we get abnormalities, such as rancid butter, "gassy" cheese, coloured cheese, or bitter cheese. Occasionally also poisonous bodies, such as tyro-toxicon, result.

Tyro-toxicon (diazo-benzene butyrate) is a poison discovered by Vaughan in cheese that had undergone a peculiar fermentation. Such cheese is not necessarily altered in appearance or taste, but has a much stronger acid reaction than usual. Tyro-toxicon can be detected chemically by neutralizing with sodium carbonate, exhausting with ether, evaporating the ethereal solution, and dissolving the residue in water. The aqueous solution strikes an orange, red, or purple colour when treated with a mixture of equal parts of carbolic and sulphuric acids. It is unstable, and present generally in only very small quantities, which are difficult of detection. It is intensely poisonous, causing dryness of the mouth and fauces, a sense of constriction in the throat, nausea, vomiting, diarrhœa, and great nervous prostration. The symptoms usually pass off in a few hours, but may end in death from collapse. Butter and cream, as well as cheese, have given rise to tyro-toxicon poisoning. In 1883–84 there occurred in Michigan, U.S.A., an outbreak of cheese poisoning, which affected 300 persons, due to tyro-toxicon (*Vaughan*), and in 1901 17 cases of tyro-toxicon poisoning occurred in Finsbury. In both outbreaks the incubation period was short (only a few hours), and the symptoms were as stated above.

Adulterations of cheese are unimportant. Starch is said to be added sometimes. The use of skimmed milk or colouring matter is not regarded as adulteration. Cotton-seed oil or other foreign fat is sometimes added in place of the abstracted cream (margarine cheese).

Analysis.—The proportion of fat to casein should not be less than 1 to 2 at the very lowest; sometimes the fat exceeds the casein. The fat may be extracted with ether, or mechanically by the Leffmann-Beam process of melting and centrifuging. The fat should be examined by the Reichert method. Water ranges from 20 to 35 per cent., fat from 35 per cent. down to 22 per cent. in good cheese, and to 1 per cent. in skimmed-milk cheese. Casein varies between 25 and 50 per cent., and salts between 3 and 6 per cent.

LARD

The internal fat of the abdomen of the pig should be absolutely free from water and from foreign fat. The addition of water, which is not now widely practised, is detected by melting the lard in a tall glass and allowing time for the water to collect at the bottom. Cotton-seed oil is the other important adulterant. It is detected by its low melting-point, high power of absorbing iodine, and reduction of nitrate of silver.

EGGS

The average weight of a hen's egg is about 2 oz., of which 10 per cent. is shell, 60 per cent. white, and 30 per cent. yolk. The white consists of albumin, with 86 per cent. water, and the yolk of albumin and fat with 52 per cent. water. The percentage composition may also be stated thus: Shell 10 per cent., albumin and fat 23 per cent., water 67 per cent.

Preservation.—Air may be excluded by coating the shell with butter, lard, oil, wax, gum, waterglass, etc., or by boiling for half a minute so as to coagulate the surface albumin. Antiseptics are also employed, e.g. the eggs are immersed in lime water, salt water, or solution of boroglyceride.

Tests are only necessary for the detection of stale or rotten eggs. Two ounces of salt in a pint of water forms a solution in which good eggs sink and stale ones float. Fresh eggs are transparent at the centre, stale eggs at the top (tested in front of a candle in a dark place).

VEGETABLE FOODS

Wheat-flour is rich in albumin and carbohydrates, poor in fat and salts of organic acids. It contains from 8 to 12 per cent. of gluten, and can therefore be made into bread. The salts are chiefly phosphates of potash and magnesia.

Examination of flour.—Flour should be free from acidity or mouldy smell. The colour should be white; a yellow colour indicates age, fermentation, or conversion of starch into dextrin and sugar.

The microscope may reveal any of the following:—

(1) *Foreign starches*, especially potato and rice, the characters of which will be described presently. (2) *Fungi*, the most common of which are sporangia of *Puccinia*. One species of *Puccinia* produces "caries" or "smut" of wheat; smut gives the flour a disagreeable smell, and the bread a blue colour. It is said to cause diarrhœa. (3) *Vibriones* and other organisms in fermenting flour. (4) *Acarus farinæ*, common in damp, inferior flour which is beginning to change. *Weevils* (*Calandra granaria*) can also be seen with the naked eye.

Adulterations and impurities.—The chief are the addition of foreign starches, mineral matters, and other cereals.

Analysis.—*Water* should not exceed 16 per cent. The more the water the greater the liability to change. *Gluten* should not be less than 8 per cent., and may reach 12 per cent. It is separated by making the flour into a paste and working it with the fingers in a stream of water until all the starch is washed away. *Ash* should not be less than 0·8 per cent. nor more than 2 per cent. If excessive, it should be tested for iron (indicating addition of clay), calcium sulphate, and magnesium carbonate. A simple test is to shake the flour with chloroform; the flour floats, but mineral matters sink. *Alum* is sometimes added during grinding.

Ergotized flour is detected by making it into a paste with dilute alkali, adding slight excess of dilute nitric acid, and then neutralizing; ergot gives a reddish-violet colour, changing to red in presence of nitric acid, and to violet in presence of alkali. Potash gives a herring-like smell with ergotized flour.

Foreign starches will be recognized under the microscope, but a few other tests are available. Bean meal gives off a characteristic smell when drenched with hot water, and may also be detected by the successive addition of nitric acid and ammonia, which strikes a deep-red colour. Potato starch grains swell up on the addition of a trace of potash in solution, which scarcely affects wheat starch grains. Pure wheat flour, made into a dilute solution in water, is turned pink on addition of iodine; but if any potato starch is present, a dark purple colour will appear.

The flour should also be put to the practical test of bread-making. It may be added that a high degree of bleaching, which is obtained by the use of peroxide of nitrogen, may be injurious. The use of "improvers," such as various phosphates, phosphoric acid, mixture of other cereals, etc., is to be discouraged. (*Hamill.*)*

Bread is made by mixing flour with water, and kneading it, so as to form dough by the cohesion of the moistened gluten. The dough is charged with carbonic acid, which occupies innumerable lacunæ and renders the mass porous. The carbonic acid is supplied by the use of yeast ("leaven") or baking powders, or by kneading the dough with water charged with carbonic-acid gas under pressure ("aerated" bread). One hundred pounds of flour make about 130 to 150 lb. of bread.

During baking a certain proportion of dextrin and sugar is formed from starch, and there are traces of lactic and butyric acid. Alum checks these changes, which are especially prone to occur if bad flour is used. Mechanically aerated bread is the whitest and most free from dextrin and sugar. About 1 per cent. of boiled potato is frequently added to the dough.

The various preparations sold under the name of **baking powders** are intended to give lightness to bread or cakes of various kinds, and the basis of them is bicarbonate of soda, combined with acid which unites with the soda during baking and liberates the carbonic-acid gas to rise through the dough in bubbles and so render the result more or less spongy. The process is precisely analogous to that by which effervescing drinks are formed by adding a solution of some acid to a solution of the bicarbonate, with the single exception that the brisk effervescence of the liquid is prevented by the greater cohesion of the dough, through which the gas can only ascend comparatively slowly and with difficulty.

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* As a war measure in 1917 the Government, through the Food Controller, authorized the addition to flour of 20-50 per cent. of substitute cereals. It will be understood that the usual standards of character and adulteration of flour, etc. are not applicable to war time.

The majority of the baking powders used have as their acid constituent tartaric acid or cream of tartar, or a mixture of these substances; but acid calcium phosphate is also used, and the powders may be divided into two classes, the *tartaric* and the *phosphatic*. "Self-raising flour" is flour to which the baking powder has been added, and with which tartaric or phosphatic preparations have been incorporated, together with sodium bicarbonate, for the purpose of producing gas when the flour is moistened. Whether in baking powders or in "self-raising flours" the preparations in which phosphates are employed as the acidifying agents are liable to large contamination with calcium sulphate. It should never exceed 10 per cent. (*Hamill.**)

Examination.—Bread should be white. A yellow or dark tint may be due to old or inferior flour, bad yeast, admixture of rye, or merely to presence of bran. Acidity may be caused by old or inferior flour. Bread is heavy and sodden if from any cause the dough has not risen sufficiently: such causes are bad yeast, bad flour, too much or too little heat, or defects in manipulation.

Water should not exceed 45 per cent. An excess lowers the nutritive value, and favours the growth of fungi. The *ash* ranges from 1·3 to 2·0 per cent. *Alum* is detected by pouring upon a slice of bread, moistened by water, a freshly made decoction of logwood chips, and then a solution of ammonium carbonate. If alum is present it acts as a mordant, and after the lapse of half an hour, or less, a strong blue colour is manifest, which is quite distinctive for practical purposes, so far as bread analysis is concerned, although magnesium carbonate would, if present, give the same reaction. Pure bread is merely stained pink by the reagents, and on drying this changes to a dirty brown. The blue given by alumina salts is permanent on drying—much more so than in the magnesium carbonate reaction.

For legal purposes it is necessary to determine the alumina quantitatively, and then a deduction must be made for the maximum amount of phosphate of alumina which may be present in pure bread. It is usual to deduct 16 gr. (of alum) per 4-lb. loaf, anything in excess of this being regarded as adulteration. In exceptional cases pure flours may contain more than this, and many analysts now allow 8 or 10 gr. per 4 lb. Alum used for purposes of adulteration usually amounts to from 20 to 40 gr. per 4-lb. loaf.

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* *See also* Dr. J. McHamill's Report to L.G.B. on Nutritive Value of Bread and Wheat Flour, 1911.

Foreign starches, especially rice and potato starch, may sometimes be detected under the microscope even after baking, but as a rule they are beyond recognition in bread. Potato makes the bread damp; the percentage of water is high, and the ash is alkaline instead of being neutral. Rice has in itself a low ash (0·85) per cent. Excessive moisture and low ash should raise suspicion of foreign flour. High ash, on the other hand, is suggestive of mineral adulteration.

The seeds of *Lolium temulentum* (darnel grass) may occasionally be ground with wheat flour, and cause vertigo, vomiting, convulsions, and other symptoms of poisoning. Various fermentations also occur in bread, producing chromogenic changes, bitter, slimy, or mouldy bread.

Barley is in the main similar to wheat in chemical composition, but contains more nitrogen, iron, and phosphates. It is liable to cause diarrhœa. Animal actinomycosis may be due to eating raw barley or other cereals upon which the *actinomyces* is epiphytic. **Oats** contain more fat and more nitrogen than wheat, and are more readily cooked, but gluten is wanting, and hence bread cannot be made of oatmeal.

Rye contains less gluten than wheat, and makes a dark, sour bread, which is apt to cause diarrhœa in those unaccustomed to its use. Ergotism results from the use of rye attacked by *Claviceps purpurea*. **Maize** (Indian meal) contains much fat, and its albumin to be made digestible requires careful cooking. Pellagra has been attributed to a fungus (*verdet*) attacking maize. **Rice** is poor in nitrogen, fat, and salts, but is very digestible.

Leguminosæ contain much nitrogen, chiefly in the form of legumin. Peas and beans are less digestible than cereals, and require prolonged gentle boiling.

Watercress grown or washed in polluted water was found to be responsible for an outbreak of enteric fever in Hackney in 1903, which shows that inspection of watercress beds is necessary. Intestinal parasites may also be derived from the same source.

Potatoes are antiscorbutic and very digestible. Good potatoes sink in a saline solution of specific gravity 1100; bad ones float.

Starch is not a simple chemical substance, but a mixture of three bodies—*granulose*, *erythro-granulose*, and *cellulose*, which are respectively turned blue, red, and yellow by iodine. Granulose is the most important of these. Boiled in water, or with oxalic or other organic acid, it is converted into "soluble starch" or *amidulin*, a soluble dextro-rotatory substance chemically indistinguishable from granulose, and giving the blue iodine reaction. If instead of organic acid a 2-per-cent. solution of sulphuric acid is boiled with the granulose or starch, the soluble starch first formed is converted into *dextrin* or *erythro-dextrin*, a sort of gum, which is dextro-rotatory, and is reddened by iodine; it is precipitated by alcohol and acetic acid, but not by tannic acid. Still further heating with sulphuric acid produces *achroödextrin*, which gives no colour reaction with iodine, and *glucose*.

Erythro-granulose is present in small proportion in wheat starch, and almost absent in potato. Its affinity for iodine is greater than that of granulose, but the red tint is completely hidden by the deep blue of the iodine-granulose. If a minimal proportion of iodine is employed, the red colour appears. Both the red and blue disappear on heating, owing to dissociation of iodine and starch, but reappear on cooling.

Starch occurs in the various farinacea in microscopic granules, which in many cases have a sufficiently characteristic appearance to indicate their origin. The granules vary greatly in size. Some are roundish, others oval, pyriform, truncated, polyhedral; some have distinctive markings, especially faint concentric rings or a hilum.

Microscopic examination of starches.—A little of the starch, in a state of fine powder, should be mixed with a drop of water, preferably containing 30 per cent. of glycerin, and put under the microscope. The principal varieties may be arranged in five classes (*Muter*):—

1. *Large oval or pyriform grains with hilum and concentric rings.*—This group includes potato starch, and several varieties of arrowroot. Tous-les-mois, or Canna arrowroot, has the largest grains of all; maranta (Jamaica or St. Vincent) arrowroot is characterized by a linear hilum at the larger end.

Potato starch grains vary greatly in size and shape; the hilum is minute, but distinct, and is placed at the smaller end.*

2. *Irregular, round, or oval grains with stellate hilum, but no rings.*—Maize starch grains are round, or polygonal with rounded angles. Bean and pea starch grains are oval and very much alike, but the former are far more uniform in the size of the grains.

3. *Round or oval grains without hilum or rings.*—Wheat starch grains differ greatly in size, and there is a characteristic absence of medium sizes; they are round and flattened. Polarized light shows a cross.

Barley starch is much more uniform. Rye starch granules, if old and dry, often present a large stellate hilum.

4. *Grains truncated at one end.*—Sago starch has a round hilum at the convex end, and faint rings; the starch grains of prepared sago have a large depression. Tapioca starch grains are smaller than sago, and some of them show signs of alteration by heat.

5. *Angular grains.*—Oat starch is often massed into little balls or clusters of grains fairly constant in size. Rice starch is smaller than oat, and pepper starch the smallest of all. Under very high power both rice and pepper show a hilum. Tahiti or Tacca arrowroot is larger than oat starch, and less uniform in size; it resembles maize, but has sharp angles.

Alcoholic beverages.—Alcohol, in dilute form and moderate dose, is oxidized (98 per cent.), and so supplies energy like food, and replaces in some degree fats and carbohydrates, but by dilating the surface blood-vessels it may cause more heat to be lost than it is itself capable of producing; and in large doses the general paralysis of cellular activity produced is so great that heat production is diminished, and the final result is a lowering of body temperature. It has a paralysing effect on nerve cells and muscular tissue, and though having at first an apparently stimulating effect on the body, it does not give staying power. It may, of course, be associated with other substances

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* Potato starch may also be distinguished from arrowroot by certain chemical tests. When mixed with half its weight of hydrochloric acid, the former gives a transparent jelly, the latter a white paste. Potato starch gives off an offensive odour when heated with sulphuric acid. Potato starch jelly made with water turns thin and sour in twelve hours, maranta not for three or four days.

(as in malt liquors) which have a definite value as food. Broadly speaking, it may be said that the effects of large doses of alcohol are the reverse of those produced by small doses (or amounts which may be taken without any elimination by the kidneys); that is to say, alcohol in large doses acts as a depressant and produces chronic irritation, which manifests itself in the stomach (inflammatory conditions, atrophy), in the liver (cirrhosis), in the brain (degeneration), etc. Such conditions are, of course, modified by individual habits and idiosyncrasies, age and sex, exercise, diet, occupation, and disease.

The three chief forms of alcoholic beverages are (*a*) malt liquors, such as beer, ale, porter, and stout (3–8 per cent. alcohol); (*b*) wines, such as the sparkling wines of the Rhine and the Moselle, champagne, hock, claret, etc. (6–18 per cent. alcohol); (*c*) spirits, as whisky, gin, rum, and brandy (40 or more per cent. alcohol). *Rectified spirit* contains 90 per cent. by volume of absolute alcohol; *proof spirit* is a mixture of 57·3 per cent. by volume of absolute alcohol and 42·7 per cent. of water. The ratio of alcohol to proof spirit being as 1 : 1·76, the amount of alcohol in any liquid being given, the amount of proof spirit can readily be calculated.

Malt beers are made by inducing yeast fermentation of sugar, derived from the starch of barley. During germination, the insoluble starch is converted into dextrine, maltose, and glucose, the process being completed by "mashing" with water at 160° F. The wort is then boiled, hops are added, and, after cooling, the liquid is discharged with yeast into the fermenting tun. Non-malt beers are made by fermenting glucose and allied substances obtained by the action of sulphuric acid upon starch. Wines are produced by fermentation of the juice of the grape, complete fermentation resulting in a dry wine, incomplete in an effervescing or sparkling wine. Spirits are prepared by the distillation of some previously fermented liquor; brandy from wine, whisky from malted barley, rum from molasses. But there are many varieties in distillery methods, and much "brandy" is made from potato spirit.

From the point of view of the medical officer of health alcoholic beverages assume importance in three ways: (1) disease caused by excessive consumption; (2) adulteration, and (3) fraudulent imitations sold to the prejudice or injury of the purchaser.[*]

The diseases commonly attributed to excessive consumption of alcohol are chiefly alimentary or nervous, producing cirrhosis of the liver and various forms of gastric disease, or alcoholic neuritis, delirium tremens, etc. There is, in addition, a large amount of disease, directly or indirectly due to alcoholism, which does not appear in death certification, and which is indicated in a general way by the relatively high death-rates of brewers, inn-servants, and innkeepers.

The **principal indices of alcoholism** are (*a*) social characteristics, (*b*) economic results, (*c*) police and criminal statistics, (*d*) morbid conditions caused by excess, and (*e*) mortality-rates. In 1915, in England and Wales, 497 deaths were attributed to "alcoholism," and 1,772 to diseases of which it was recorded as secondary cause. The death-rate from alcoholism declined from 113 per million in 1900 to 53 per million in 1914.

Arsenic in beer.—Of adulterants introduced accidentally or otherwise into alcoholic beverages, arsenic in beer is perhaps the best example. In 1900 there was wide prevalence of illness in South Lancashire and elsewhere, which was, after a time, identified by Reynolds as a form of arsenical poisoning, and traced to the consumption of beer from certain breweries in which highly arsenical brewing sugars had been used. These were found to be derived from a common supply, in the manufacture of which, from starch, arsenical sulphuric acid had been used. The arsenic (As_2O_3) found in the sulphuric acid was 1·9 per cent., in the artificial sugars 0·008 to 0·131 per cent. (0·56 to 9·17 gr. per lb.), in beer often $\frac{1}{4}$ to $\frac{1}{2}$ gr. per gallon, and in one sample 3 gr. per gallon. This danger vanishes if care is taken to use acid free from arsenic, but a more persistent source of arsenic in beer was found in the malt itself. The usual process of drying the malt in kilns with exposure to fumes of gas-coke or anthracite entails risk of contamination by arsenic in such proportions as $\frac{1}{80}$ gr. per lb. The most effective remedy here would seem to be drying out of contact with the fumes; but much can be done by selection of non-arsenical fuel, by careful construction and cleanliness of the kiln, so as to avoid arsenical deposits on ledges falling into the malt, and lastly, by "brushing" the malt, whereby the fibrils (which readily become charged with arsenic) and surface dust are removed. At Halifax, in 1902, the use of arsenical malt* caused a local outbreak of poisoning among beer-drinkers.

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[*] The Central Control (Liquor Traffic) Board, appointed in 1915 as an emergency body during the war, provided for the systematic dilution of alcoholic beverages. The Board also reduced the hours of sale to 5½ per diem, prohibited "treating" and credit sales, and restricted off sales and spirits, with beneficial results.

It was estimated that in the outbreak of 1900 at least 3,000 persons were attacked in Manchester and Salford alone, and 6,000 in all. Many attacks were fatal. For some time the nature of the epidemic was obscured by the unusual character of some of the prominent symptoms, more especially the peripheral neuritis and pigmentary changes. In the main, the attacks and their severity bore relation to the consumption of beer, but some of those attacked had apparently consumed but little, while some heavy drinkers escaped lightly. Similar variations in toleration and susceptibility are met with in the therapeutic use of arsenic. A high degree of insusceptibility is recorded in the case of the Styrian peasants, who take large doses without apparent ill effect, and it may be assumed in the case of some arsenic workers. It is important to note, as an aid to diagnosis, that arsenic can be found not only in the urine but in the hair.

The Reports of the Royal Commission on Arsenical Poisoning, dealing primarily with the outbreak of 1900, call attention also to some risk of presence of arsenic in glycerin, phosphates, boric acid, colouring matters, and other food ingredients. The Commission recommended a penal limit of $\frac{1}{100}$ gr. of arsenic per pound, or per gallon, in any food substance.

In the Marsh-Berzelius test, the suspected material is first treated with hydrochloric acid in a suitable vessel. It is then placed in the Marsh-Berzelius apparatus, which consists of a flask for the generation of hydrogen from which passes a drying tube and a glass tube drawn out in the middle and at the end. In this apparatus hydrogen is obtained from pure zinc and pure sulphuric acid, and the substance under examination is placed in the flask. Hydrogen and arseniuretted hydrogen escape through the drying tube, containing calcium chloride, and thence pass into the fine glass tube, which is heated over a Bunsen burner. The arseniuretted hydrogen is decomposed, and the arsenic is deposited on the wall of the narrow part of the tube, and so forms a "mirror." Finally, this mirror is compared with standard mirrors prepared from known quantities of arsenic (e.g. $\frac{1}{10}$, $\frac{1}{50}$, $\frac{1}{25}$, and $\frac{1}{100}$ gr. per gallon). The Reinsch test is less reliable.

The question of adulteration of alcoholic beverages is too large for consideration here, but, as an illustration, mention may be made of recent work in connexion with **brandy**. In 1876, owing to an outbreak of *phylloxera*, a parasite affecting and destroying vines, the usual output of genuine brandy from the Cognac district was curtailed, and artificial preparations were substituted for the genuine article. In the absence of any official or legal standard, brandy may be defined as an alcoholic liquor the spirit of which is obtained by distillation, in a pot-still, from the juice of the grape, and which should contain not less than ·80 parts by weight of esters (calculated as ethyl acetate) per 100,000 parts by volume of absolute alcohol.

Whisky may be defined as consisting of spirit derived from malted barley, or a mixture of malted or unmalted barley or wheat, distilled in a pot-still. A spirit thus produced contains at least 380 parts of secondary bodies (higher alcohols, esters, aldehydes, etc.) per 100,000 of absolute alcohol.

Vinegar has been defined as a liquid derived wholly from alcoholic and acetous fermentations: it must contain not less than 4 grm. of acetic acid (CH_3COOH) in 100 c.c. of vinegar; it must not contain arsenic in amounts exceeding 0·0143 mg. in 100 c.c. of vinegar, nor any sulphuric or other mineral acid, lead or copper, nor may it contain any foreign substance or colouring matter except caramel. Malt vinegar is derived wholly from malted barley or wholly from cereals the starch of which has been saccharified by the diastase of malt.

Summary as to relation of food and health.—1. Certain essential constituents of diet may be deficient or in excess.

2. Poisonous substances may be derived from the vessels in which the food has been kept. Thus tinned provisions (fruit, fish, or meat) may become poisonous, and cider kept in lead-glazed vessels may cause lead-poisoning.

3. Injurious substances may be added or substituted accidentally, or by way of adulteration or preservation, or by improper processes of manufacture, or by the drugging of animals before death.

4. Certain kinds of food are liable to be occasionally poisonous, even in the fresh state (mussel-

poisoning), or when grown under unfavourable conditions (oysters, watercress, etc.).

5. Putrefactive changes may have commenced.

6. Poisonous substances may be developed, either as a result of parasitic growth (fermentation) or from, at present, unknown causes (tyro-toxicon).

7. The flesh or milk of an animal suffering from certain specific or parasitic diseases may impart the disease (e.g. tuberculosis, trichinosis, hydatids).

8. Food, and especially milk, may become infected by virus of human or animal origin.

It should not be forgotten that disease in the individual, or more rarely idiosyncrasy apart from disease, may render certain kinds of food injurious which to ordinary persons are wholesome. Lastly, there are certain accessories of diet which may be injurious if used injudiciously (alcohol, tea).

In suspected cases of food-poisoning the filling-up of the following Table will show what articles of diet (if any) were consumed by all the sick and by none of those who escaped attack (*see* Form of Inquiry, p. 124).

	M. 36. Ill.			F. 34. Ill.			M. 12. Not Ill.			F. 5. Not Ill.		
	Mon	Tu.	Wed.	Mon.	Tu.	Wed.	Mon.	Tu	Wed.	Mon.	Tu.	Wed
Beef . . .	×	..	×	×	..	×	×	..	×	×	..	×
Pork . . .	..	×	..	..	×	..	..	..	..	..	..	..
Fish . . .	..	×	..	..	..	..	..	×	..	..	×	..
Potatoes . .	×	×	×	×	×	×	×	×	×	×	×	×
Cabbage . .	×	×	..	×	×	..	×	×	..	×	×	..
Bread . .	×	×	×	×	×	×	×	×	×	×	×	×
Butter (fresh) .	×	×	×	×	×	×	..	..	..	..	..	..
,, (salt) .	..	..	..	..	..	..	×	×	×	×	×	×
Cheese . .	×	×	×	..	..	..	×	×	×	..	..	..
Milk (cooked) .	×	×	×	×	×	×	×	×	×	×	×	×
,, (uncooked)	×	×	×	×	×	×	..	×	×	×	×	×
etc. etc.												

CHAPTER V

SOIL

The chemical and physical constitution of the soil and the configuration of its surface have an important bearing upon many hygienic questions, particularly in relation to water-supply, burial-grounds, sewage land treatment, sites for buildings, and the prevalence of certain diseases.

Temperature.—The daily variation of temperature ceases to be perceptible at about 3 or 4 ft. from the surface. The annual variation is unimportant below 6 or 8 ft., very small below 24 ft., and vanishes at 40 ft. (*Galton*) or 50 to 100 ft. (*Parkes*). The maximum is later as the distance from the surface increases, and at Edinburgh it was found that in trap-rock at a depth of 24 ft. the maximum was in January and the minimum in July. The absorption of heat, assuming that the exposure is equal, is determined mainly by the nature of the soil and the presence or absence of vegetation. The absorption by sand being taken as 100, that of clay is about 70, chalk 60, and humus or mould 50. Radiation varies in like manner, but is generally greater than absorption. Trees and shrubs intercept the sun's rays, and on the other hand check evaporation from the surface of the soil, the net result being to render the ground cool and moist in winter, and cool and dry in summer when the leaves are out. The evaporation from leaves is very great, and tends to moisten and cool the air, and abstract water from the soil. Pettenkofer calculated that an oak tree with 750,000 leaves had in the summer months an evaporation equal to eight times the rainfall, and in Algeria the *Eucalyptus globulus* has been found to absorb and evaporate twelve times the rainfall.* Herbage lessens absorption of heat by the soil, and also true radiation, but increases evaporation and convection owing to the vast surface of the blades of grass. Grass, therefore, like trees, renders the soil cooler and drier, and more equable in temperature.

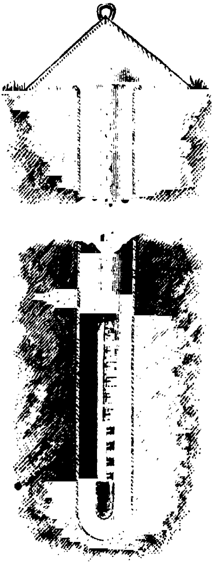

Fig. 19.—Earth thermometer.

Earth temperatures are usually determined by thermometers mounted in paraffin or wax, suspended by a chain at the required depth in the soil (1 to 4 ft. or more), and withdrawn at daily or other intervals for reading (Fig. 19). An iron tube driven vertically into the ground, protected by open wooden covers, affords a passage for the thermometer. Systematic records are usually kept of the daily readings of two earth-thermometers (at 1 ft. and 4 ft.). At greater depths the internal heat of the earth produces an appreciable effect, causing a rise of about 1° F. for every 55 ft.

Moisture.—At a certain point below the surface in permeable soil, all the interstices are full of water, to the complete exclusion of air. This *subsoil water* or *ground-water* extends downwards to the next impermeable stratum. In marshy ground the surface of the subsoil water may coincide with that of the ground itself, and under ordinary conditions it may be from 2 or 3 to 100 ft. or more below the ground-level. The surface of the ground-water is not necessarily horizontal, or parallel with that of the ground. It flows (usually towards the nearest watercourse or the sea) with a velocity that varies with the permeability of the soil, the steepness of the gradient, and the absence of obstruction by roots of trees.* The level is affected by that portion of the rainfall which percolates through the soil; also by the height of water in adjoining streams or seas, and other conditions modifying the facility of outflow—artificial drainage, etc. Sometimes the range of rise and fall does not exceed a few inches, but it is more usually several feet.

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* As regards the air, forests render both the daily and annual temperatures more equable, and increase the humidity (*Galton*).

Above the level of the ground-water the soil, though aerated, is still kept moist by capillary attraction, by evaporation from below, by rainfall, and by the movements of the ground-water. The soil constantly loses moisture by evaporation from the surface, both directly and through vegetation.

The moisture of a sample of soil is estimated by weighing it before (B) and after (A) drying it on a water-bath. Then $\frac{B - A}{B} \times 100$ = percentage weight of water in sample. The level of the subsoil water is necessarily that of the water in surface wells, and may be gauged by lowering into the well a cord or rod bearing little cups at short intervals, or more simply by means of an index connected by a cord with a float.

When the ground-water rises, it forces air out of the soil, and at the same time may pollute wells by bringing into them the washings of impure soil. As the ground-water falls again it leaves the soil moist and aerated, conditions favourable for fermentative and putrefactive processes in organically polluted soil.

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* In Munich Pettenkofer estimated the velocity of the ground-water to be 15 ft. per day.

Damp ground is rendered dry, and the level of its ground-water permanently lowered, by subsoil drainage, surface drainage, and opening the outflow. For subsoil drainage "agricultural" pipes, i.e. unglazed porous pipes, are laid loosely end to end at the bottom of deep trenches, and covered in. The interval to be allowed between the parallel drains will depend upon the openness of the soil.

Air ("ground-air") is present in all rocks except the very hardest, above the ground-water level. It fills all the space unoccupied by water or solid particles. The proportion by volume varies greatly with the porosity and other conditions of the soil; loose sand may contain 50 per cent., and humus several times its own volume of air. Ground-air contains moisture, organic matter of animal or vegetable origin, and sometimes NH_3, H_2S, and CH_4. Carbonic acid is in excess, and increases with the depth; it also varies greatly according to the nature of the soil and the intensity of the local chemical changes that are going on in it. Oxygen is in relatively small proportion, and decreases with the depth. At 13 ft. Fodor found 14 per cent. of CO_2 and 7·5 per cent. of oxygen. Many causes combine to keep the ground-air in constant movement, among them being wind, percolation of rain, variations in temperature and barometric pressure, and rise and fall of ground-water.

The percentage volume of air in a sample of rock of specific gravity G may be determined by finding its weight when dry (A), and when saturated with water (B). Then $\frac{B - A}{A} \times G \times 100 =$ percentage of air. For loose soils Pettenkofer used two graduated burettes connected together at the bottom by a clamped tube. One burette was filled with water, and the other with dried and crushed sample soil. Water was then allowed to pass upwards through the soil, displacing all the air until it just reached the surface.

$$\frac{\text{No. of c.c. of water used}}{\text{No. of c.c. of dry soil}} \times 100 = \text{percentage of air.}$$

All rocks are more or less permeable, and therefore capable of containing air or water in their interstices. A cubic yard of granite or marble holds about a pint of water, sandstone 25 gallons, and sand 50 gallons.

Chemical composition.—The mineral constituents of soil are of the utmost variety, but only the organic matters will be considered here. The soil undergoes constant pollution by dead animal and vegetable matter and excreta, which are as constantly being removed by putrefaction, nitrification, and the influence of vegetation. Apart from such obvious examples as graveyards, manured fields, sewage-farms, and the like, unintentional pollution of the soil goes on upon an enormous scale, especially around dwellings. Nitrates are commonly found in abundance in the soil of any long-inhabited place. Carbonic acid and other simple compounds are formed concurrently; offensive gases are given off during putrefaction, but are deodorized and oxidized by passing through aerated soil. Vegetable matters are more persistent. They may undergo putrefaction and slow oxidation, but it is not certain that nitrification takes place.

Sometimes the natural level of the ground is artificially raised, constituting what is known as "made soil." This may be ordinary earth, but in the neighbourhood of towns it is a common practice to fill up hollows and to elevate low-lying sites with trade refuse, ashes, household refuse, and even excremental refuse. From such soil the impurities fairly rapidly disappear, owing to oxidation and washing by rain. Sanderson, Parkes, and Savage found that in about three years most of the vegetable matters in cinder refuse had disappeared; wood, straw, and cloth were rotten but still distinguishable. Free exposure to air and rain and free outlet for drainage will accelerate the process of purification.

Bacterial content.—Soil, particularly near the surface, contains many bacteria. These have been divided into groups according to function. The **decomposition** or **denitrification** organisms (many of which are anaerobes) abound particularly in soils possessing a high degree of organic matter, and their rôle, being analytic, is to break down compounds of ammonia and nitrogen, yielding free nitrogen, CO_2, water, ammonia, and sometimes nitrites. These latter bodies are oxidized by the **nitrifying** organisms first discovered by Schlösing and Muntz in 1877. Nitrification is a synthetic process, and is performed in two stages: first, an oxidation from ammonia bodies to nitrites, carried out by the nitrous organisms (*nitroso-bacteria*); and secondly, the oxidation of the nitrites into nitrates by the agency of the nitric organisms (*nitro-bacteria*). For the performance of their function these organisms require pabulum, oxygen, a base with which nitric acid when formed can combine, and a favourable temperature. Both organisms are widely distributed in superficial soils (within 12 in. of the surface), and act together and in conjunction for the common purpose of nitrification. Their range of action is only limited by the amount of calcium present in the soil. In organic solutions, nitrous organisms thrive and nitric organisms do not, the reverse being true in inorganic solutions containing nitrites, in which nitrous organisms are incapable of the oxidation process. The presence of peaty or humous matter appears to preserve the vitality of nitric organisms during the fermentation of ammonia. It is owing to the fact that sewage contains vast numbers of these denitrifying and nitrifying organisms that the "bacterial treatment" by contact bed is possible. A third group of allied organisms are the **nitrogen-fixing** bacteria found in soil and in the roots of Leguminosæ; their function appears to be, directly or indirectly, the fixation of free nitrogen (symbiosis). This may be performed under the symbiotic condition by the leaves, by distribution in the soil of the root nodules, or by the nodules themselves. It is thus, in part, that clover, vetches, peas, beans, and other leguminous crops increase the amount of fixed nitrogen in the soil, particularly where it is especially small in quantity. Associated with these groups of bacteria are a number of saprophytic organisms, the function of which is not known. Houston has described certain acid-forming microbes in peat.

It would be difficult to over-estimate the value in the economy of nature of the three groups of organisms to which reference has been made: they remove organic matter and waste animal products, they carry on the oxidation processes which are applied in the bacterial treatment of sewage, and they fix free nitrogen. Some, at any rate, of the **pathogenic organisms** are also known to live and multiply in soil, and at least three find in such a medium a favourable nidus. The bacillus of tetanus (*B. tetani*) is common in the soil and dust of certain districts, either in a bacillary form or in the resting stage of spores. The presence of this bacillus in jute factories is possibly due to its attachment to the roots of the *Corchorus* in the soil of Bengal. The organisms of quarter-evil (symptomatic anthrax) and malignant œdema are two other examples of pathogenic bacteria in soil. Possibly also the typhoid bacillus is able to assume a vegetative or saprophytic existence outside the body, surviving in ordinary earth, whether virgin or polluted with sewage. If so, it follows that outbreaks of enteric fever may be due to the dissemination (for example, by wind or flies) of infective soil dust.

Sewage added to ordinary garden soil appears to lead to a temporary increase only of sewage microbes at the expense of soil microbes, the latter eventually ousting the sewage microbes in the struggle for existence. Sandy soil so treated does not recover for some months. The chief kinds of bacteria resulting from such soil treatment are indol-producing bacteria, gas-producing bacteria, spores of *B. enteritidis sporogenes*, *B. coli* and its allies, and streptococci (*Houston*). Further, it should not be forgotten that soil has the power of destroying some pathogenic germs as well as sewage organisms.

Soil and disease.—Among important specific diseases, anthrax, tetanus, malaria, enteric fever, cholera, diarrhœa, and yellow fever are closely concerned with telluric conditions. Dampness of soil is favourable to phthisis and diphtheria, and, according to some authorities, to rickets also. Goitre is often credited with a more indirect relation to the soil (p. 79).

Enteric fever and cholera exhibit in certain localities a somewhat definite inverse relation to the fluctuations of the level of the ground-water. In Munich, Leipsic, and elsewhere, it has been found that a fall in the subsoil water, and especially a rapid fall after an unusually high level, is followed by an outbreak of enteric fever. These observations, extending over several years, led Pettenkofer to the conclusion that the conditions requisite for an enteric outbreak are (1) a rapid fall (after a rise) in the ground-water, (2) pollution of the soil with animal impurities, (3) a certain earth temperature, and (4) the presence of a specific organism in the soil. These conditions imply a warm, moist, and well-aerated soil, containing pabulum suitable for the specific microbe. On the other hand, the association of falling ground-water with enteric outbreaks is not observed in other localities. It has not been traced in England, as a rule, and, indeed, outbreaks have occurred with rising ground-water.

Enteric fever, cholera, and yellow fever are often endemic, a fact that in itself is strongly suggestive of telluric relations. They are also found to flourish best where the soil is polluted with excremental or other animal matter. The same may be said of diarrhœa, and Ballard has shown that outbreaks of summer diarrhœa have a close relation with the earth temperature at a depth of 4 ft. Soil may become infected by the spores of anthrax or tetanus, and retain the infection for an almost indefinite time.

Buchanan believed not only that phthisis mortality bears a direct relation to dampness of subsoil, i.e. to height of ground-water, but also that, when the ground-water is lowered and the soil dried by artificial drainage, the recorded phthisis mortality falls; but this view must be accepted with reserve (*see* p. 466). It appears, besides, that dampness of soil is favourable to all affections of the respiratory system, including bronchitis and pneumonia. In the absence of definite evidence the popular theory that damp and cold soils are conducive to rheumatism and all manner of catarrhs may be provisionally accepted. A high level of ground-water (say within 5 ft. of the surface) is, therefore, objectionable, and it is preferable that it should be 15 ft. or more from the surface; but frequent and extensive fluctuations of level are probably worst of all. The presence of clay, like high ground-water, renders a soil "cold."

Building sites.—Porous soils, like sand or gravel, with low ground-water, are the warmest, and in the main the most healthy; but they are also the most liable to organic pollution, and the ground-air moves freely in their interstices. Clay, and especially a clay slope, affords a far more healthy site than gravel or sand containing organic matter, the impure ground-air from which is constantly forced out of the soil, and is also liable to be drawn into the interior of houses through the basement. The most unhealthy site of all would be a hollow with impure, gravelly soil and high and fluctuating level of ground-water; the most healthy, the summit of a slope with dry, pure, sandy or gravelly soil, and low and stationary level of subsoil water. The foot of a slope often receives the drainage from the higher ground, and there is the same liability to damp at the junction of an upper porous and a lower impervious bed, especially if the strata dip towards the point in question. In tropical regions it is necessary to take into account the tendency of winds to pass up valleys and ravines, from lower to higher levels, during the day, and in the reverse direction at night. The proximity of marshy or "malarious" ground may be dangerous, even if the site itself is otherwise free from objection. Herbage is beneficial, for the reasons already stated, and so too are trees, unless they are allowed to interfere with light and circulation of air. Manured lands have not been proved to be hurtful; but irrigated lands, and especially rice-fields, which give off organic matter and much moisture are often injurious; and in Italy rice-grounds are not allowed within 14 kilometres of cities, or 1 kilometre of small towns (*Parkes*). There seems to be no good evidence against well-managed English sewage-farms. "Made soil" is usually impure and unfit for building sites. The objection is greatest when the deposit is recent (within three years) and contains excremental o other organic refuse, and is so placed in hollows tha drainage and aeration are impeded.

Geological formations.—The following is summary of Parkes's conclusions in respect to th healthiness of certain geological formations, but, as h points out, they are of less importance than th immediately local conditions:—

Granitic, metamorphic, and trap rocks, millston grit, and clay slate are impervious and generall healthy. The slope is great, vegetation not excessive air dry, and water pure. Marshes are infrequent These rocks, when weathered and disintegrated, ar alleged to be unhealthy.

Limestone, oolite, and magnesian limestone (*dolomite*) have also much slope, and water passes o readily. Marshes may occur, even at great heights Magnesian limestone is the worst and oolite the best Goitre and calculus may be met with.

Chalk is healthy if permeable and free from clay The air and water are pure. Goitre and calculu are less common than in limestone districts. Marl chalks are impermeable, and therefore damp and cold and may be "malarious."

Sandstone, if permeable, is healthy. The air and soi are dry, but the water is often impure. An admixture, or substratum, of clay may render the site damp

Sand is healthy if pure and dry. Many sand soils are unhealthy, e.g. when the subsoil water i high and organic impurities are present. The wate is liable to contain salts of the alkalis, lim magnesia, and iron, and is often unfit for drinkin purposes.

Gravel is healthy, except in hollows where th ground-water is high. Gravel hillocks are the healthiest of all sites. The water is usually pure.

Alluvial soils, including clay and dense mar are usually unhealthy. Water neither runs off nor through them, marshes are common, the air is moist, and the water often impure with lime and soda salts. The deltas of great rivers present these alluvial characters in the highest degree, and should not be adopted for sites without thorough drainage.

Much may be done to improve a site not naturally healthy. If damp it may be drained, or trenches may be cut around it so as to intercept the subsoil water on its way from higher ground. By such means the level of the ground-water will be lowered and its fluctuations lessened. Damp places near the site may be drained or filled in, and the site itself may be artificially elevated if necessary. Trees are often desirable for shelter or ornament, but should not be allowed to interfere with light or circulation of air. Rank or superabundant vegetation must be cleared away, but short grass is beneficial.

CHAPTER VI

HOUSE SANITATION

DWELLING-HOUSES, hospitals, residential institutions, and schools should be erected on sites where it is possible to avoid dampness and impurity of soil, as well as a cold, cheerless aspect and exposure to violent winds. A dry, porous soil, such as sand, gravel, or chalk, should therefore be chosen, in a well-drained situation, preferably on a slope, facing S.W. or S.E., and not hemmed in by high trees or high buildings. (*See* p. 179.)

General construction.—Most of the ordinary building materials are pervious to air and water to a greater or less extent. Galton states that with a temperature of 40° F. outside, and 72° F. within, the volumes of air passing through a square yard of wall vary according to the material, as follows:—

Sandstone	4·7	cubic ft. per hour.
Quarried limestone .	6·5	,, ,,
Brick	7·9	,,
Limestone	10·1	,,
Mud	14·4	,,

The thickness of the wall is supposed to be the same in all cases. Mortar, cement, and concrete[*] are also permeable, and the caustic lime they contain absorbs carbonic acid until it becomes saturated. Wood in its natural condition absorbs water, and the inevitable joints and crevices admit of the passage of air and water. Bricks are usually 9 in. × 4½ in. × 2¾ in. They are porous and absorbent, but if of good quality make excellent building material. Stone varies greatly in consistence and durability. Portland stone is much used in the metropolis.

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[*] *Mortar* consists of sharp sand and slaked lime in the proportion of 3 to 1. Frequently inferior material is worked up into mortar. *Portland cement* is made by grinding chalk and mixing it with blue clay and river mud, then burning it in a kiln and grinding it to a fine powder. "Compo" is a mixture of Portland cement with sand for external plastering in two coats, a rough coat composed of 1 part cement to 5 parts sand, and a fine coat of 2 parts fine sand and 1 part cement. With this material walls are "rendered." *Concrete* is composed of 3 parts broken ballast, 2 parts sand, and 1 part lime or cement.

By painting, varnishing, and other means the inner surfaces of walls, floors, and ceilings can be rendered impervious, and walls lined with glazed bricks or the finer cements (Parian) are scarcely permeable.

The disadvantages of porous materials are obvious, and the air admitted in this way, though small in amount, is at least doubtful in purity. Pervious walls are liable to be damp and cold. Air passing through them in either direction is filtered, and the wall becomes charged with organic impurities. This is especially the case with the inner surfaces, and in hospitals it is now customary to render the walls and floors impervious as far as possible. The **exclusion of damp** and impure ground-air, by means of impervious basements, is absolutely necessary in all inhabited buildings. This may most conveniently be effected by covering the basement in every part with a layer of concrete 6 in. thick, as required by the Model Bye-laws, but other materials may be employed. It has been proposed to cut off the communication with the soil still more thoroughly by elevating the house upon pillars and arches, thus allowing free play of fresh air beneath it. If there are no cellars, the same result may be attained in some degree by constructing the lowest floor a foot or two above the ground-level, and freely ventilating the space beneath by means of large air-grates. In houses built without precautions of this kind the entrance of ground-air through the basement is inevitable whenever the air in the interior of the house is warm, and therefore lighter than that outside.

Measures must also be taken to prevent damp from rising in the walls by capillary attraction. For this purpose a **damp-course** must be provided, that is, a continuous horizontal course of glazed earthenware, sheet lead, two layers of ordinary roofing slate set in cement, $\frac{3}{4}$ in. of asphalt, stoneware slabs, two courses of Staffordshire bricks, or other impervious material, of the full thickness of the wall, above the highest point at which the wall is in contact with the earth, and below the lowest timbers or floor supports (Fig. 20). It is undesirable to allow the soil to be in contact with the wall of any room or cellar, and this can usually be obviated by excavating it on the outside to below the level of the floor so as to form a 'dry area," but if this is impracticable the device shown in the Model Bye-laws may be employed; the wall is made hollow up to a point above the ground level, and two damp-courses are inserted, one at the level of the bottom of the cavity, and of

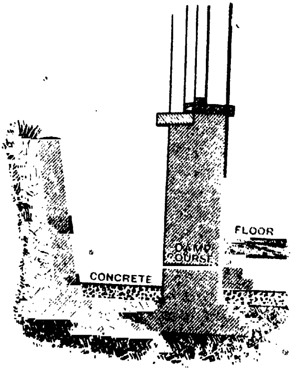

Fig. 20.—Damp-course.

course beneath the floor-level, the other at the top of the cavity, and therefore above the level of the ground outside (Fig. 21). In this way the inner wall is completely isolated from the soil. Hydraulic lime should also be used in the mortar.

The necessity for free ventilation extends to all closed spaces, including those below floors. There is a tendency among builders to use air-grates so constructed and arranged as to allow but little air to pass. If the ventilation is insufficient, the air becomes damp and musty, and the fungous growth known as "dry-rot" (*Merulius lacrimans*) is liable to set in. As regards the upper storeys, however, the ventilation through the boards and ceiling is usually sufficient to prevent dry-rot, unless the floor is covered with oilcloth or otherwise rendered impervious. Fire-proof floors are now becoming common.

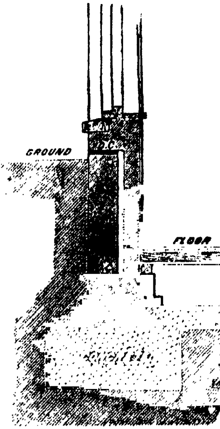

Fig. 21.—Double damp-course. Soil abutting upon hollow wall.

The **thickness of walls** is often regulated solely by considerations of stability, and the choice of materials by their cheapness and convenience, but regard should also be had to warmth and exclusion of damp. It is sometimes advantageous to make the outside wall hollow or double, or even to fill in the hollow of a double wall with pitch or cement. The outer surface may also be made impervious by paint, tar, cement, or slate. Damp walls may be due to ascending moisture where there is no damp-proof course, or to overflow from roof-gutters and rain-water pipes, etc. The walls separating one house from another should be carried up to or above the roof in every part. Any communication beneath the roof is objectionable for many reasons, including danger in case of fire or infectious disease in one of the houses. The Model Bye-laws require for the external walls or party-walls of houses a minimum thickness of 9 in., increasing according to a prescribed scale when the height exceeds 25 ft. or the length 30 ft. Walls should be properly bonded by Flemish bond (bricks placed transversely and longitudinally by turn) or English bond (a course of longitudinal alternating with a course of transverse). (Figs. 22, 23.)

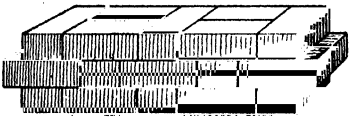

Fig. 22.—Flemish bond.

The roof itself affords very little protection from the extremes of temperature, and the rooms immediately beneath it, if intended for occupation, should have a "false roof" or ceiling over them, so as to leave an intervening air-space below the slates.

The **size of the rooms** will, of course, be regulated by convenience and by the purpose for which they are intended. As a rule, the height should not be less than 10 ft., but extreme height is not desirable unless means are provided for carrying away the hot and impure air from the upper part before it condenses and falls again. A window opening top and bottom and placed in an external wall is essential in every inhabited room, and as far as possible a due-northern, and therefore sunless, aspect is to be avoided. Besides the window, every room should have an open chimney, or at least some permanent and effectual means of ventilation not entirely under the control of the occupant. Rooms beneath the ground-level are liable to damp, stagnation of air, and deficiency of sunlight, and should never be used as bedrooms. A central hall or staircase of the full height of the house, with ventilating windows at the top, is useful in promoting free circulation of air throughout the building.

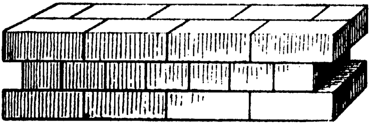

Fig. 23.—English bond.

For the sake of securing a share of sunlight in every room, it is preferable that rows of houses should run north and south, and that square buildings should have angles in those directions.

Every house should have both in front and rear an **open space** at least equal in length to the height of the building, in order to allow sufficient light and ventilation for the rooms on the lowest floor. The arrangement of houses in courts or small closed squares is objectionable, since the air cannot circulate freely. Cul-de-sac courts and courts entered under archways or by high-walled alleys are on this account to be deprecated. Nor should buildings be so placed in relation to each other as to prevent free access of sunlight and air. The space in front of houses should be of a minimum width of

36 ft. for a street of more than 100 ft. in length, which itself must be at least 24 ft. wide (in London 40 ft.). Model Bye-laws provide for at least 150 superficial ft. at the rear of houses. The London Building Act crystallizes the principle that the amount of space at the rear shall be proportionate to the height of the building, and it contains a number of regulations as to building in new and old streets. Streets should not be of less width than the height of the houses in them, and a line drawn from the ridge of the roof to the foot of the wall opposite, front and rear, should not make an angle of more than 45° with the ground. The practice of building over back-yards which prevailed in Central London last century is wholly pernicious, for such a system leads to back-to-back houses.

Back-to-back houses are dwellings in which through ventilation cannot be obtained owing to the fact that the back wall of the house is a party wall belonging in common to another dwelling at the rear, so that the two dwellings are in contiguity, back to back. Such houses usually have dark and ill-ventilated sculleries, pantries, storerooms, or living-rooms, almost devoid of sunshine; in the absence of back yards the closets and ashpits are built in blocks, often at an inconvenient distance and in a public position; the absence of a curtilage is a serious inconvenience; and, lastly, the construction of back-to-back houses leads to overcrowding of houses on the land. The effect of back-to-back houses on the health of the occupants is manifested in an increased general death-rate, chiefly attributable, according to Darra Mair, to (*a*) common infectious diseases, (*b*) diarrhœa, (*c*) pneumonia, bronchitis, and other pulmonary diseases, and (*d*) certain infantile causes of death of a developmental nature or due to malnutrition and debility. Tatham has shown that in such houses mortality-rates are higher, by comparing the death-rates in Salford (26·1 per 1,000), where there were no back-to-back houses, with the death-rates where 18 per cent. of the houses were of this character (29·1 per 1,000), and where 50 per cent. were of this character (37·3 per 1,000). Many similar returns have been made. Darra Mair, who in 1910 carried out one of the most complete inquiries of this kind, found that the corrected average annual death-rate from all causes (1898–1907) in thirteen selected and comparable towns was greater in back-to-back houses than in through houses by 15 per cent. Mortality from phthisis showed an excess amounting to 12 per cent. in back-to-back houses built in rows, but not in such houses built to admit of side ventilation. The excess of mortality from all causes occurred chiefly in children and in persons of 65 years of age or upwards. Bye-laws do not now permit the erection of back-to-back houses, which are also prohibited under the Housing and Town Planning Act, 1909.

The **interior of a house** will of course be arranged according to the taste and circumstances of the owner. Walls may suitably be rendered in plaster (lime mortar, or cement mortar) and finished by lime-washing, as in outbuildings, whitewashing with "whiting" (chalk, size, and alum), distempering, painting in oils, or papering. Painting of wood, ironwork, etc., has many advantages, and tends to cleanliness and preservation. It may frequently be washed. New papers should not be pasted over old ones, as this leads to filth, and, in tenement houses, to verminous conditions. The wall should be "stripped" and cleansed, and, if necessary, rendered with size before the new paper is put on.

New houses are constructed under the supervision of the S.A., and in accordance with bye-laws prescribing all details necessary for sanitary purposes.

Old houses are very often wanting in many points now regarded as essential for the health of the inmates, and it becomes a matter of considerable difficulty to decide how far it is practicable to enforce modern requirements in such houses. If the defects are such as to be prejudicial to the health of the inhabitants, it is the duty of the **S.A.** to require the necessary repairs or alterations to be carried out, and it is incumbent upon the **M.O.H.** and Inspector of Nuisances to bring such cases to the notice of the Authority for that purpose. Very often it is not possible to effect such alterations as would be considered satisfactory in new premises, and a certain degree of latitude has to be allowed. No hard-and-fast line can be drawn between that which is essential and that which is desirable, and a similar difficulty frequently arises in deciding whether a house is or is not fit for habitation. Sometimes the question is only one of degree, in matters regarding which fixed standards are impossible. Several causes may combine to render a house unhealthy.

Next to the external construction or fabric of the house come the important matters of *water supply*, *ventilation*, *warming*, *lighting*, and *drainage* These will now be dealt with seriatim, a separate chapter being reserved for drainage and sewerage.

Water supply to houses.—General matters regarding water supply have already been dealt with (*see* Chap. III., p. 39). From the domestic point of view the important points are (*a*) quality, (*b*) quantity, (*c*) effective protection from pollution, and (*d*) easy accessibility.

The Public Health Act, 1875, and the Public Health (Water) Act, 1878, give powers to the **S.A.** to enforce supply of water to individual houses, groups of houses, and villages.

Under the 1875 Act the **S.A.** can only insist on a supply to a house if the cost does not exceed the water-rate authorized by any local Act in force in the district, or 2d. per week, or such other cost as the **L.G.B.** may, on the application of the **S.A.**, determine to be reasonable.

The **Public Health (Water) Act, 1878,** applies to every rural **S.A.**, and also to such urban **S.A.s** as the **L.G.B.** may order (sections 3 and 11). Every rural **S.A.** shall see that every occupied dwelling-house within their district has, within reasonable distance, an available and sufficient supply of wholesome water. If the **M.O.H.** reports that an occupied house is without such supply, and the **S.A.** are of opinion that such a supply can be provided at a reasonable cost (the interest on which, at 5 per cent., shall not exceed 2d. or 3d. per week, as the **L.G.B.** may, on the application of the **S.A.**, determine to be reasonable in the circumstances), the **S.A.** may require the owner (subject to appeal to the **L.G.B.**) to provide such supply within a specified time, and, in case of default, may themselves carry out the necessary works at his expense. It remains, however, the duty of the **S.A.** to provide any part of their district with a supply of water, in cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at a reasonable cost (s. 3).

The owner of any dwelling-house in a rural district that may be erected or rebuilt from the ground-floor after the date of this Act shall not permit such house to be occupied without a certificate from the **S.A.** that it is provided with a sufficient and available supply of wholesome water, such certificate to be based on the report of the **M.O.H.** or inspector (s. 6). If the **S.A.** provide a stand-pipe for water supply, they may levy water charges upon every dwelling within 200 ft., as if the supply were given on the premises; not, however, upon such houses as have a good supply within reasonable distance, from another source, unless water from the stand-pipe is used by the inmates (s. 9).

Every rural **S.A.** must, through their officers or otherwise, provide for the periodical inspection of the water supply of their district. The same powers of entry upon premises are given as are conferred by ss. 102 and 103 of the Public Health Act, 1875, in respect of nuisances (s. 7).

The Metropolis Water Act, 1871, gave power to the Board of Trade to make regulations controlling the supply to houses by water companies. The Public Health (London) Act, 1891 (s. 48), states that a dwelling-house shall be deemed unfit for human habitation if it is without a proper and sufficient supply of water. New houses in London have to be certified in this respect.

Ventilation.—One of the most important matters in connexion with buildings, particularly dwelling-houses, is ventilation. Taking the average frequency of respiration as 16 per minute, and the average volume of each breath as 30 cubic in., the volume of air expired is about 17 cubic ft. per hour, and if it were possible to carry this immediately away (as is done in the case of divers) a fresh-air supply of 17 cubic ft. per hour would suffice. In practice, the expired air cannot be prevented from mixing with the rest, and we have to determine how much fresh air is needed to dilute down the respiratory impurities to a permissible point, assuming that the whole of the air in the room is equally contaminated.

When the carbonic acid in the air of a room exceeds 0·6 volume per 1,000, the air begins to be perceptibly "close" *to a person entering from the open air*, and it is usual to adopt this as a standard of purity, and to aim at introducing a sufficient supply of fresh air to keep the carbonic acid at or below this point. (*See* p. 2.)

A thousand cubic feet of fresh air, containing 0·4 cubic ft. of carbonic acid (*see* p. 2), can therefore take up 0·2 cubic ft. more without exceeding the limit of 0·6. As already stated, an average man gives off about 0·6 cubic ft. of carbonic acid per hour, so that $\frac{0{\cdot}6}{0{\cdot}2} \times 1{,}000$, or 3,000 cubic ft. of fresh air per hour, are needed to maintain the standard of purity. If other values be adopted for any of the preliminary data, the volume of fresh air needed will be proportionately modified. In general terms, if

A = No. of c.f. of CO_2 in 1,000 c.f. of fresh air = 0·4,
C = proposed max. limit of CO_2 in the air of the room,
R = No. of c.f. of CO_2 given off per head per hour = 0·6,
F = volume of fresh air required per head per hour to maintain the standard C,

Then $F = \dfrac{R \times 1{,}000}{C - A}$, and for n persons the required volume becomes $\dfrac{n \times R \times 1{,}000}{C - A}$, or $\dfrac{n \times 600}{C - 0{\cdot}4}$.

Example 1.—What hourly supply of fresh air is needed for a hall containing 100 persons, in order that the air of the hall may not contain more than 0·7 part of carbonic acid per 1,000 volumes of air?

Answer: $\dfrac{100 \times 600}{0{\cdot}7 - 0{\cdot}4} = 200{,}000$ cubic feet.

Example 2.—If 12,000 cubic feet of fresh air per hour are supplied to a room containing 10 persons, what proportion of carbonic acid will be found in the air of the room?

The formula $F = \dfrac{n \times 600}{C - A}$ becomes

$$12{,}000 = \frac{10 \times 600}{C - 0{\cdot}4},$$

Hence $C = 0{\cdot}9$ per 1,000 cubic feet.

It is of course assumed that an equal volume of impure air is removed to make way for the fresh air.

Carnelley, Haldane, and Anderson found that the determination of carbonic acid alone is not a satisfactory measure of the impurity of the air in other respects. There is no definite connexion between the number of microbes and the amount of CO_2, but in general a high proportion of CO_2 is accompanied by a high proportion of organic matter. Nor does it, of course, include other impurities, such as sulphur.*

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* The English gas companies are usually legally required to supply gas containing less than 20 gr. per 100 cubic ft. In London hitherto the maximum has been 17 gr. in summer and 22 gr. in winter. In some provincial towns as much as 30 gr. is allowed.

As gas forms in burning about half its volume of CO_2, the products of combustion (on a standard of 20 gr. of sulphur per 100 cubic ft.) would contain less than 0·5 gr. of sulphur to 500 litres of CO_2. If the sulphur were oxidized to SO_2 this would correspond to about one volume of SO_2 to 1,500 volumes of CO_2, which would not produce any perceptible effect in the atmosphere of a room. The sulphur contained in crude unpurified lighting gas is present chiefly as H_2S, about one-tenth being present in other forms (as CS_2). Gas which is purified from carbon bisulphide is greatly superior from a hygienic standpoint to gas which is only purified from sulphuretted hydrogen.

As regards the more specific diseases, the **injurious effects of deficient ventilation** are obvious. Crowding in a common atmosphere has long been known to be disastrous in typhus and erysipelas, and more recent experience has established this in respect of diphtheria, influenza, and other maladies, both as regards transmission of infection and intensification of type, and retardation of recovery. Ventilation has greatly lessened phthisis in barracks and other institutions, and with cleanliness it has banished typhus from prisons, and hospital gangrene and erysipelas from hospitals. The success of the open-air treatment in camp hospitals and in sanatoria for phthisis has the same significance. It is evident that all diseases in which the breath is infectious must necessarily be more readily transmissible when the expired air is rebreathed in a concentrated form.

Apart from this, there is abundant evidence of the gain in comfort, general health, and longevity under conditions of adequate fresh-air supply, and conversely of higher death-rates (general, and from bronchitis and other non-specific causes), impaired health, anæmia, headache, and depression among those whose lives are largely spent in ill-ventilated rooms. Some of these effects are felt at once by susceptible persons on entering a room in which others work without discomfort, but the precise relation between them and the several physical conditions which impurity of air connotes is not clear. Experiments have been made, with conflicting results, by removing one or other of these conditions while leaving the rest to increase in a degree far beyond that met with in practice. Thus, in experiments by Haldane and Lorrain Smith, carbonic acid alone did not appear to disturb respiration until it had risen to about 300 parts per 10,000; nor did diminution of oxygen do so until the proportion had fallen from 21 to 12 per cent. of the air.

The **principles of effective ventilation** are (*a*) sufficient cubic capacity and absence of overcrowding, (*b*) proper inlets and outlets, rightly placed, (*c*) cross-ventilation, (*d*) a moderate temperature and humidity, (*e*) constant movement of the air, and (*f*) the air itself being fresh, pure, dustless, and germ-free.

Air-space.—With ordinary appliances, and under the average atmospheric conditions of the climate of England, the air of a room cannot be changed more than about three times per hour without causing an inconvenient amount of draught. Hence, in order to supply 3,000 cubic ft. of fresh air per hour, we should have an air-space for each person of at least 1,000 cubic ft. In calculating this, only the available air-space should be taken into account, deduction being made for furniture and other solid objects. It must be remembered, too, that air stagnates in nooks and corners, and the useful part of the air-space is that in which the air moves freely. For these and other reasons it is more difficult to provide for the efficient ventilation of a small room than of a large one, the air-space per head being the same in each case; but, on the other hand, the transpiration through walls, ceilings, and floors is relatively greater in small rooms, owing to their higher ratio of surface to air-contents. The extent and practical importance of this transpiration is proved not only by CO_2 determinations but by the experience gained in sulphur fumigation, where the leakage of the gas is rapid and demonstrable in spite of every precaution to prevent its escape through openings.

A further reservation is necessary. Above a certain height air-space ceases to be useful, since it does not assist ventilation; and in such circumstances increase in height cannot compensate for inadequacy in length and breadth, that is, floor-space. There may be overcrowding and even suffocation in the open air. It is a common rule, in rooms of moderate size, to disregard height above 15 ft. in calculating air-space, but the limit varies with the floor area. In the special rules for certain dangerous processes under the Factory Act, the requirement of at least 400 cubic ft. of air-space per head is coupled with a condition that height

AVERAGE RESULTS OF ANALYSES OF AIR IN SLEEPING-ROOMS BETWEEN 12.30 AND 4.30 A.M. (*Carnelley, Haldane, and Anderson.*)

Cubic ft. per head.	Temperature (Fahrenheit)	Carbonic acid per 1,000 vols.	Organic matter (vols. of oxygen required per million vols. of air).	Microbes per litre.
100– 180 . .	55°	1·15	15·1	80
180– 260 . .	54°	1·07	15·1	49
260– 340 . .	53°	1·03	11·8	32
340– 500 . .	57°	0·92	8·4	42
500–1,000 . .	54°	0·86	5·6	6
1,000–2,500 . .	58°	0·67	3·9	9
2,500–4,000 . .	57°	0·79	5·0	18

above 14 ft. is not to be taken into account. In hospitals and schools there is a standard of floor-space per bed, or desk, apart from mere cubic capacity.

The experiments summarized above were made in Dundee. They tend to show that about 1,000 cubic ft. per head are sufficient, and, indeed, the impurities were somewhat greater when very large space was provided, owing probably to imperfect ventilation.

The same observers compared houses of one, two, three, and four rooms, in regard to impurity of air and mortality from different causes among the inmates. They found that the smaller the tenement the greater was the impurity of the air, as shown by increase of carbonic acid, microbes, and organic matter. The death-rate increased in like manner, and especially among children. Comparing one-roomed with four-roomed houses, the general death-rate was doubled, and the death-rate at ages below 5 years quadrupled. The increase was most marked in diarrhœa, measles, whooping-cough, bronchitis, and pneumonia. The same general conclusions are well illustrated in the following table :—

FINSBURY. DEATH-RATES (per 1,000 living), 1905-6.

Size of tenements (number of rooms).	Census population, 1901.	All causes.		Principal zymotic diseases.		Phthisis.		Respiratory disease (excluding phthisis).	
		1905.	1906.	1905.	1906.	1905.	1906.	1905.	1906
One . .	14,516	32·7	39·0	3·4	6·4	3·5	3·4	6·4	8·3
Two . .	31,482	19·5	22·5	2·8	6·5	2·1	2·3	5·2	4·3
Three . .	21,280	12·8	14·8	1·8	2·6	1·3	1·4	2·8	2·9
Four or more	33,185	6·6	6·4	0·7	0·8	0·8	0·9	1·4	1·2
The borough *	101,463	18·9	20·7	2·0	3·7	2·1	2·3	4·4	4·0

* Including institutional deaths.

The actual air-space obtained in practice frequently falls very far short of 1,000 cubic ft. per head, even in large private houses. In registered common lodging-houses the minimum is usually 300 cubic ft. per head, but varies according to the regulations of the different local authorities, and in working-class dwellings it is frequently much less still. The London Education Committee require 120 cubic ft. per head as a minimum in primary schools (96 cubic ft. in infant schools). The lowest standard expressly sanctioned by law is that for canal-boats, namely, 60 cubic ft. per head for adults, and 40 for children. It is important to bear in mind that air-space is chiefly valuable as making ventilation possible without "draught," and not as a store of fresh air. The foul air of an average occupied bedroom in the morning is a proof that proper ventilation has not been provided, whatever the magnitude of the cubic space. No bedroom, however large, ever contains a sufficient supply of fresh air for the night, but the larger the room the more readily can efficient ventilation be contrived. A thousand cubic feet of space per person is ample, if the air is changed three times per hour, but in itself a thousand cubic feet of air is a sufficient supply for one person for twenty minutes only, if the CO_2 is to be kept down to 0·6 per 1,000.

The objection to draught is largely dependent upon its chilling effect, so that in hot weather, or when the fresh air is warmed artificially, the air of a room may be changed more rapidly than three times an hour, and in that case a somewhat smaller cubic space may be sufficient.

Although the carbonic acid of expired air diffuses readily, the organic matter is less volatile, and hangs about in stagnant clouds unless dissipated by local currents. Hence the composition of air in an occupied room is not uniform, even at the same level, though for practical purposes it may usually be assumed to be so. In a large room occupied by many persons both the local currents and the foci of pollution are numerous, so that the composition of the air is much more uniform than in a small room occupied by one person. If from any cause the air passing out of the room is not the most impure, the remaining air will be found to exceed the theoretical degree of impurity. The outlet should be at or near the highest point, since expired air, being warm and moist,[*] is lighter than ordinary air, and ascends at first to the upper part of the room.

The **fresh-air inlets** or fans should be arranged as far as possible so as (i.) to avoid draughts impinging upon the occupants, (ii.) to secure diffusion of the current, (iii.) to provide for movement of the air, and (iv.) to counteract the tendency of the fresh air (if cool) to sink to the lowest level. This may be effected by giving it an upward direction on entering.

In measuring a room for the purpose of calculating the air-space, recesses and projections may be taken separately, and then added to or deducted from the total. A similar procedure will obviate any difficulty in cases where the ceiling is not horizontal throughout.[†]

The ventilation of a room or building may be "natural" or "artificial," the latter term being applied to mechanical means for extraction or propulsion of air, and the former to all other forms of ventilation.

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[*] The vapour of water is lighter than air. The volumes occupied by 18 parts by weight of water vapour, 32 of oxygen, and 28 of nitrogen are equal; these proportions being, of course, those of their respective molecular weights.

[†] Very often only right angles are met with, so that the floor area = length × breadth, and the cubic capacity = area × height. The following rules cover most of the other conditions likely to occur in practice.

Area of triangle = base × height × $\frac{1}{2}$. (Euclid I. 41.)

Area of an irregular four-sided figure. Divide into two triangles, by joining two opposite angles. Find area of each triangle, and add together.

Area of a circle = $(\text{diameter})^2 \times 0{\cdot}7854$.

Area of a semicircle = $(\text{diameter})^2 \times 0{\cdot}3927$.

Area of segment of circle = $\text{chord} \times \text{height} \times \frac{2}{3} + \frac{(\text{height})^3}{2 \times \text{chord}}$.

Area of an ellipse = long diameter × short diameter × 0·7854.

Capacity of a dome = area of base × height × $\frac{2}{3}$.

Capacity of a cone or pyramid = area of base × height × $\frac{1}{3}$.

Natural ventilation is dependent upon wind (perflation and aspiration), upon diffusion and local currents due to differences between internal and external temperatures, and still more upon local currents determined by artificial heat, as in chimneys or ventilating gas-lights, although these last may perhaps more properly be considered as artificial means of ventilation. In short, natural ventilation is dependent upon diffusion of gases, and the effects of pressure and temperature upon them. (*See* p. 5.)

Air finds its way into a room by the **doors and windows,** however close-fitting, and to a less extent through brick or stone walls, ceilings, and floors. These leakages are very small if a proper fresh-air inlet has been provided. Such inlets may be window openings, or ventilating fire-places or stoves, or special openings (ventilators). Windows should be made to open at top and bottom, but it is desirable to have in addition some means of admitting air at all seasons without draught. This may be done by having double windows, or one or more double panes, and providing an opening at the bottom of the outer and at the top of the inner one, so as to admit fresh air in an upward current. Louvred panes and several modifications of "hit-and-miss" ventilators are also available. A simple and effectual device (Hinckes-Bird's) is to place a board beneath the lower sash, propping it up and filling in the space below while providing a way for an upward indraught between the two sashes. Another plan is for the upper part of the window to open in hopper fashion, or to be hinged below so as to fall forward and admit air into the room as by a Sheringham valve. The Chaddock window is a useful form of ventilating window for institutions.

Ventilating fire-places have an air-chamber at the back of the grate, heated by the fire. Fresh air brought by a pipe from outside is warmed in the hot chamber, and then passes into the room. There are many varieties, among which Galton's is the earliest and one of the best. Ventilating stoves are in use, the fresh air entering through a coiled pipe exposed to the heat of the stove.

Special ventilators are of varied types, from simple openings through the wall to the most complex arrangement. **Perforated bricks** cause little draught, the holes being conical with the wider ends inside, so that the air stream slackens as it passes through the wall, and is diffused upon entering the room. **Sheringham's ventilator** (Fig. 24, D) is a small vertical flap door in the wall near the ceiling, balanced by a counterpoise and hinged below so as to fall forwards towards the room; it is cased in at the sides and front so that the current can only pass upwards. **Tobin's ventilator** (Fig. 24, A) consists of a large upright tube rising 5 ft. or more from the floor; fresh air from outside passes up this tube and into the room. **Ventilating cornices** are made, consisting of a double channel of perforated metal, cold fresh air being brought into the room by the lower channel, and vitiated air being received into the upper channel and carried to the chimney or other outlet; another plan is to carry a perforated inlet tube along the cornice on three sides of the room, and a similarly perforated outlet tube along the fourth side. A hollow perforated metal beam, interrupted by a diaphragm at the centre, may be taken across the room, one half serving as

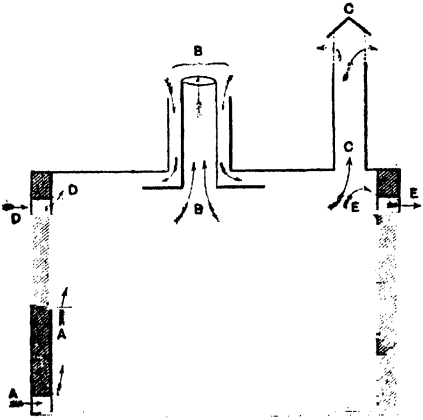

Fig. 24.—Ventilators.
A A, Tobin's; B B, McKinnell's; C C, simple ventilating shaft, with cap; D D, Sheringham's (acting as inlet); E E, Sheringham's (acting as outlet).

an inlet and the other as an outlet, according to the direction of the wind. **McKinnell's ventilator** (Fig. 24, B) consists of a larger outer and a smaller inner tube, carried upwards through the ceiling; fresh air passes in between the tubes, and is dispersed on entering the room by a horizontal flange upon the inner tube; the inner tube, which is equal in sectional area to the inlet, and projects beyond the other both above and below, carries off impure air. Another device is a vertical shaft divided longitudinally into two or four separate channels, along which currents in opposite directions will always establish themselves. Workrooms may be ventilated by means of a perforated ceiling of zinc or paper, over which is a chamber open to the outer air on every side. An open-tiled roof, or one not underdrawn, allows much ventilation.

Some of the preceding are intended to act as inlets, but all are liable to become outlets. Other kinds of ventilators are, like chimneys, designed as **outlets** only. An opening may be made from the room into the chimney near the ceiling, reflux of smoke being prevented by a number of little valves of mica (Boyle's valves) which, in the absence of up-current, close by their own weight, owing to the forward tilt of the latticed framework to which they are attached. Ventilating gas-lights are made, in which the products of combustion are collected by means of a bell cover or glass globe, and conveyed away by a tube; this tube can be surrounded by a larger one, and the heated space between the two made to act as a further extraction shaft. A similar use may be made of chimneys, the smoke being contained in a central metal tube, leaving a heated air-space all around it, which serves for extraction. Or outlet pipes from the higher part of the room may be carried upwards for some distance in or close to the chimney so as to utilize its heat in promoting an up-current. Extraction tubes may, of course, be carried from any part of the room, with or without taking advantage of these various convenient sources of heat, and they may be provided with cowls.

The size of openings required for the efficient ventilation of an occupied room under average conditions is about 48 sq. in. *per head*, namely, 24 as inlet and 24 as outlet, but, according to Parkes, no single inlet should exceed 60 and no outlet 144 sq. in.

Supplies of fresh air should be taken from suitable points free from risk of contamination, and, if necessary, the air may be screened through metal gratings, canvas, cotton-wool, etc. It may be washed by passing it through spray or a film of water, or by being made to impinge upon a tray containing water, and it may be warmed by means of ventilating fire-places or stoves, or by coils of hot-water or steam tubes at the inlet. If warmed, there is advantage in introducing fresh air at or near the floor-level; but if cold, it is necessary to avoid draughts which might impinge upon any person in the room, and therefore the air is delivered at a higher level and with an upward direction.

Outlets should be as near the chimney as possible; the air in that part is warmest and most impure, so that the worst air is removed with maximum velocity. Above all, *cross-ventilation* is necessary.

Any barometric pressure P may be regarded as produced by the weight of a column of air *of uniform density* and of height H. **Montgolfier's Rule** affirms that air under pressure will rush into a vacuum with a velocity equal to that acquired by a body falling from the corresponding height H, which velocity may be determined by the formula $V_2 = 2gH$, g being the acceleration due to gravity (32·18 ft. per second), and V the velocity required. Thus, under standard conditions of barometer and thermometer, H is about 5 miles, or 26,400 ft., so that $V_2 = 2 \times 32{\cdot}18 \times 26{,}400$, and V = about 1,300 ft. per second.

If, however, the air under pressure P passes not into a vacuum but into space containing air under a low pressure p, the formula requires modification, the velocity being dependent upon the difference between P and p. It becomes necessary to calculate the height h of a uniform column of air (of the same standard of density as was adopted in determining H), which would give the pressure p.

The formula then becomes $V_2 = 2g\,(H-h)$, and in this form it is applicable to problems of ventilation.

For example, it may be required to determine the theoretical velocity of up-draught in a vertical* flue x ft. long, leading from a room containing air at a temperature $t°$ into the open air of lower temperature $T°$. An inlet for cold air is presupposed. The column of heated air in the flue may be regarded as balanced against an equally high column of cold air outside in a sort of U-tube, and as yielding to the greater weight of the colder and less rarefied column; and the (unequal) weights of these two columns correspond to P and p. The barometric pressure at the level of the top of the flue may be neglected, since it affects both columns alike. Then, taking the density of the outside air as the standard, the height x may be put for H in the formula, and it only remains to determine h, the height of the heated column when reduced to the same standard density. Air expands with heat to the extent of 0·002 of its volume for each degree F.,* and hence 1 volume at T° becomes, at $t°$, $1 + 0{\cdot}002\ (t - T)$, so that the column of hot air of height x at $t°$ corresponds to a height $x \times \frac{1}{1 + 0{\cdot}002\ (t - T)}$ at the standard temperature T. This, then, is the value of h, and

---

* The *vertical* height only must be taken, even if the course of the flue is oblique or bent.

$$V_2 = 2g\left(x - x \times \frac{1}{1 + 0{\cdot}002\ (t - T)}\right).$$

Since $\sqrt{2g}$ is approximately 8·0, the formula may conveniently be written

$$V = 8\sqrt{x - \frac{x}{1 + 0{\cdot}002\ (t - T)}}.$$

If, as an example, the external and internal temperatures are respectively 40° F. and 60° F., and the height of the flue 20 ft.,

$$V = 8\sqrt{20 - \frac{20}{1 + 0{\cdot}002\ (60 - 40)}}.$$

Hence the theoretical velocity of draught is 7·1 ft. per second, and this multiplied by the sectional area of the flue gives the number of cubic feet discharged per second.

The theoretical velocity is subject to correction for friction, which varies directly as the length of the tube L and the square of the velocity, and inversely as the diameter D, that is as $\frac{V_2 L}{D}$. In practice an allowance of ¼, or even ⅓, has to be made for friction, which is also increased by angles in the course of the flue.

The following formula by De Chaumont is convenient for ascertaining the relation between the size of the opening and the hourly delivery of air:—

$$D = 200 \times \phi \times \sqrt{{\cdot}002 \times x \times (t - T)},$$

where D = delivery of air, in cubic feet per hour,

ϕ = the sectional area of the tube, or of the inlet or outlet, in square inches,

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* Strictly speaking, this is accurate only when T = 32° F., but the error is immaterial for the present purpose.

x = height of heated column of air, in feet,
t and T = the internal and external temperatures respectively.

Thus, if the heated column be 20 ft. in height, the internal and external temperatures 60° F. and 40° F., and the required delivery 6,000 ft. per hour, the formula will give the sectional area necessary:—

$$6000 = 200\,\phi\,\sqrt{\cdot 002 \times 20 \times (60 - 40)},$$
$$\phi = 33{\cdot}56 \text{ sq. in.}$$

The linear velocity with which air passes through an opening is determined experimentally by an *anemometer* (*see* p. 33), which should be placed, not at the centre, but about two-fifths of the diameter from the side of the opening, so as to obtain the mean velocity. Very delicate anemometers are made, consisting of four light metal vanes mounted obliquely upon a common axis, the revolutions of which are indicated automatically upon dials. The registering apparatus can be thrown in or out of gear by a spring catch while the vanes are revolving, so that the time can be determined accurately. The linear movement observed during one minute, or less, is readily converted into velocity per hour or second, and this, multiplied by the sectional area of the opening, gives the cubic discharge.

Artificial ventilation involves either propulsion or extraction of air, the establishment of a *plenum* or *vacuum* in the room to be ventilated. In the **plenum system** fresh air, which if necessary can be warmed, washed, or screened, is propelled into the building. Fresh air may be driven into a room or building by revolving fans or other motors; vitiated air may be forced out or extracted by means of fans, steam jets, a heated outlet shaft, or steam or hot-water coils in or near extraction flues. The fans used for the purpose have vanes set obliquely upon a rapidly revolving axis, and work in a closed box or tube so as to propel a constant current of air of any required volume and velocity, somewhat after the manner of an Archimedean screw. Steam allowed to escape in a powerful jet into a flue is capable of carrying with it 200 times its own volume of air. Gas burnt at the foot of an extraction shaft may be made to carry off 1,000 times its own volume of air.

Heat is by far the most generally employed extracting power in the **vacuum system.** Ordinary fire-places, chimneys, and ventilating gas-lights act in this way. Special extraction shafts, with gas jets or furnaces at the bottom, are common. Mines are ventilated by means of a furnace at the foot of the upcast shaft, air being drawn down another shaft and made to traverse the whole of the workings on its way to the upcast. A similar plan is adopted in steamers, the upcast being a space around the funnel and boilers, a contrivance which has been applied also to house chimneys by confining the smoke, etc., to an iron tube passing up in the centre of the chimney shaft. Extraction is necessary where dust and fumes have to be drawn away at the point of origin, but is attended with some disadvantage from the difficulty of controlling the sources from which the supplies of fresh air are drawn, since it rushes in through all available openings. Provision may, however, be made at suitable points for free admission of pure air, which may be warmed, cooled, moistened, washed, or screened as it enters. When propulsion is adopted, the air is taken from one source only, and, being more under control, is more readily subjected to such heating or other treatment as may be needed. (For factory ventilation, *see* p. 672.)

The advantages of artificial ventilation are its constancy under all conditions and the facilities which it affords for regulating the source and amount of fresh air, and the preparatory treatment as to temperature, moisture, and purification. Natural ventilation is, of course, less costly, but is inconveniently subject to atmospheric conditions, and is inadequate for theatres, factories, and other large buildings. It is insufficient in the tropics.

In an ordinary room the chimney is the most important outlet when a fire is burning, air passing up with an average velocity of 4 or 5 ft. per second. In the absence of a fire the chimney still acts in some degree as an upcast, and ought on no account to be closed, unless a downward current establishes itself temporarily, and causes annoyance by its sooty smell.

To **test the value of any particular scheme** of ventilation it is necessary to consider (*a*) the cubic capacity of the room to be ventilated, and the number of occupants for whom fresh air is to be provided on a scale of 3,000 cubic ft. per head per hour (2,000–2,500 for children); (*b*) the possibilities of pollution or exhaustion of the contained air by gas-burners, etc.; (*c*) the efficiency of the means provided, whether natural or artificial (inlets, outlets, velocity of air, its temperature, etc.), and the degree in which the means are effectively maintained; and (*d*) the application of physical, chemical, and bacteriological tests to the contained air (watery vapour, temperature, CO_2, bacteria, etc.).

Warming is closely connected with ventilation. The principal methods in use may be classed as open fires, gas fires and stoves, hot air, and pipes containing hot water or steam. Some of these heat the room by radiation, warming the surfaces while leaving the air in it cool; some by convection, warming the air of the room and thus making it drier; some in both ways. Again, some (e.g. open fires) carry off large volumes of air besides their own products of combustion; some (e.g. gas or other stoves) only little; some (hot pipes) none at all; while others, and especially fender stoves, do not ventilate but add to the impurity of the air.

(*a*) Ordinary **open fires** are extravagant in regard to fuel, and it is estimated that only about one-eighth part of the potential heat is utilized in warming the room, the rest being lost in unconsumed smoke and cinder, and in the hot gases passing up the chimney. The heating effect is very unequal in different parts of the room, being chiefly confined to the vicinity of the grate, and cold currents pass along the floor. They are, however, most effective ventilators, and present a more cheerful appearance than stoves or hot pipes.

The principal practical points in regard to the construction of open fire-grates are summarized by Teale as follows: (1) Use as much firebrick and as little iron as possible; (2) the back and sides should be made of firebrick; (3) the back of the fire-place should lean over the fire, the "throat" of the chimney should be contracted; (4) the bottom of the fire should be deep from before back; (5) the slits in the bottom grating should be narrow; (6) the bars in front should be narrow; (7) the space beneath the fire should be closed in front by a close-fitting iron shield, or "economizer," thus excluding cold air almost completely from the bottom of the fire, so that the fuel as it sinks is entirely burnt up, leaving only a fine ash, which drops into the space beneath. Another means of preventing waste of fuel is to make the bottom of the grate of solid fireclay, as in the various "slow combustion" grates; and the same principle may be applied to ordinary grates by laying an iron plate upon the bars at the bottom of the grate.

Coke is the residue, consisting almost entirely of carbon and mineral ash, left in the retorts when all the combustible gases have been driven off by heat in the process of gas-making. It is smokeless and less costly than coal, but it is difficult to light and makes a dull fire. The prevention of smoke, and the complete utilization of the gases and other products obtainable from coal by distillation, are important public advantages.

(*b*) **Gas-fires** have much of the bright and attractive appearance of open fires. The gas is mingled with a considerable volume of air before ignition, as in a Bunsen burner, and the intensely hot but non-luminous flame impinges upon pieces of asbestos or iron, which become red- or white-hot, giving out light and heat. Simpler forms are also made with ordinary luminous burners, the light and heat from which are thrown forward by metal reflectors; oil-stoves are made on the same principle. In any case an adequate flue to carry off the fumes is essential.* A gas-fire burns from 10 to 20, or more, cubic ft. per hour. It is economical and cleanly in use, creates no smoke, and can be lighted, extinguished, or regulated in a moment. Ventilating gas-stoves are made, but the ordinary gas-fire, unless it be composed of incandescent fragments of asbestos in an open grate, is less effectual than an open fire in promoting ventilation. If the flue is too small, as is very often the case, the air becomes dry and oppressive, and there is risk of carbonic oxide escaping.

(*c*) **Stoves** for coal and coke, as used in England, are commonly made of cast iron, the smoke and products of combustion being conducted by an iron flue to the chimney, or to the outside air. The fire may be more or less open, or hidden from sight, but in any case the waste of heat is less than in ordinary fire-places, the sides of the stove and also the flue contributing to the heating power. As a means of extraction of vitiated air a stove is inferior to the ordinary open fire, although there is no difficulty in utilizing the hot flue for the purpose of producing an up-current in a chimney. There are also many forms of ventilating stoves, fresh air being brought in through special pipes, which in their course are exposed to the heat of the stove; in the "Calorigen" a coil of the fresh-air inlet pipe is placed inside the stove. Stoves tend to make the air hot and dry, an objection which may be met by placing vessels of water upon them. A more serious difficulty is a burnt smell which is apt to result from their use, and a tendency to give off carbonic oxide, the source of which is a matter of some doubt. It has been attributed to oxidation of the organic matter in the air by contact with the heated iron, this being also assigned as the cause of the burnt smell. Oxidation of the carbon in the cast iron is another suggested explanation; and it has been found experimentally that red-hot cast iron is pervious to carbonic oxide, and even reduces carbonic acid to carbonic oxide, so that the gas found in the room may originate in the fire itself. Wrought iron offers far greater resistance. The joints, both of the stove and the flue, should be made strong and air-tight, and, in order to minimize the risk of giving off carbonic oxide, it is desirable to line the stove with fireclay, to coat it with silicate, or to use earthenware or wrought iron in place of cast iron. Stoves can only be approved from a sanitary point of view if they (*a*) are provided with proper chimneys; (*b*) are of such a pattern that they cannot become red hot, or otherwise contaminate the air; and (*c*) are supplied with fresh air directly from the outside.

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* The consumption of gas is relatively large and not limited to hours of darkness. Besides CO_2, sulphur acids and traces of carbonic oxide are given off. The condensation of fumes, which is claimed for some gas stoves, is at best only partial.

(*d*) **Hot air** is advocated by some authorities as the best mode of warming houses, as well as public buildings. This may be done upon the large scale by warming the fresh air in the basement, and conveying it thence to all parts of the house along the passages or by special channels. The same end is attained in some degree by placing a stove or fire-place in the hall. Warm air may be supplied to single rooms by the ventilating grates or stoves already referred to, or by allowing the fresh air to enter through a coil of hot pipes. The air can be moistened and, if need be, purified by filtration or washing.

(*e*) Warming can also be effected by means of **hot water or steam** circulating in a system of closed pipes. The pipes may be carried round one or more sides of a room, near the floor, either open or concealed behind a skirting-board. Several turns or coils may be used at points where more heating power is required, and it is convenient to warm the fresh air at the inlets by the same means. Hot water is usually employed for heating purposes at a temperature below 212° F. (180°–200°). The circulation is dependent upon the water being hotter, and therefore lighter, in the tube through which it leaves the boiler than in that which brings it back. Hence the boiler is placed at the lowest point, and the centrifugal and centripetal pipes are respectively connected with the top and bottom of the boiler. A feeding cistern, and vents for the escape of air and steam, are provided at the highest point. About 12 ft. of 4-in. iron pipe are allowed for every thousand cubic feet of air-space to be warmed. The system should be so planned with valves and connecting pipes as to allow of "short-circuiting," so that the heat may be turned on or cut off from any part at will. Hot water may also be used under pressure at temperatures considerably exceeding 212° F. (300°) on Perkins's system. Strong ½-in. iron pipes are used, and, instead of a boiler, part of the pipe is carried through the fire. Steam coils may be used at high or low pressure in like manner. The systems which may be recommended for heating large buildings are: (*a*) low-pressure hot water with separate boiler, and with or without ventilating radiators, for churches, schools, theatres, cottage hospitals; (*b*) hot-water forced circulation, for hospitals, workhouses, asylums, etc.; and (*c*) indirect and plenum systems of heating (with ventilation) in prison cells and other places in which fires and stoves would be unsuitable.

Lighting.—The first requisite for good lighting is *adequacy*, and the unit of illumination is the "foot-candle,"[*] that is, the illumination produced by a light of one standard candle at a point of a surface one foot from the source and so placed that the light strikes the surface at right angles. Thus, 1 candle 1 ft. from the surface is 1 foot candle, 50 candles at a distance of 1 ft. is 50 foot-candles, and 50 candles at 10 ft. distance is 0·5 foot-candle.[†] Light should also be constant and uniform, without glare and without casting extraneous shadows on the point to be illuminated. It may be natural or artificial. **Natural light** is admitted by the roof (top lighting) or windows (lateral lighting). Unsatisfactory natural lighting may be due to deficient daylight, insufficiency of window area, artificial obstruction, or dirty windows or walls. **Artificial lighting** is usually obtained by use of coal gas, oils, or electric light. Cannel-coal gas is more illuminant than bituminous-coal gas. The chief results of the burning of coal gas are an increase in CO_2 and watery vapour, raising of temperature, with some production of sulphurous acid and other constituent bodies. Each cubic foot of gas pollutes the atmosphere to the same degree as one adult person. The best form of gas illumination is now commonly obtained by the use of an incandescent-mantle burner. Oil-lamps give fair results, but raise the temperature and give off CO_2 and watery vapour. Electric light is the most hygienic form of illumination. No oxygen is used up, no CO_2 or moisture is produced. Unsatisfactory artificial lighting may be due to the provision of too few or too weak light sources, antiquated methods, neglect of upkeep, artificial obstruction, shadows, and wrong placing of sources. (*See* Report on Lighting in Factories, 1915, Cd. 8000.)

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[*] On the continent of Europe the *meter-candle* is the unit (= about $\frac{1}{10}$ of a foot-candle).

[†] Over the "working area" of a workroom illumination at floor-level should be not less than 0·25 foot-candle; in roadways, 0·05; on table, bench, or desk, according to fineness of work, etc., 1 to 8 foot-candles.

The results of inadequate illumination are damage to eyesight and personal health, various forms of domestic insanitation, accidents in factories and workshops, often accompanied by diminution in output of work and lack of discipline.

Inspection of houses.—The following schedule includes the principal points that may require attention. The headings are numerous, but are meant to be chiefly suggestive, so that no important detail may be overlooked. A very few notes will often suffice in practice. As in all other investigations, it is wise to make explicit written notes on the spot, and to insert negative as well as positive results of inspection.

Address.

Occupier.

Owner.—Name and address.

Site.—Elevation, aspect, slope. Proximity to hills, valleys, watercourses. Nature of soil. Dryness.

Surroundings.—House detached, semi-detached, in a row, back to back. Access of light and air. Obstruction by trees, high grounds, or other buildings. Open space at front, back, sides [stating area]. Proximity [stating distance in feet] of stables, cowsheds, pigstyes, manure heaps, foul ditches, stagnant water, offensive accumulation, offensive trades, or other sources of effluvia.

Yard and outbuildings.—Condition as to cleanliness, paving, drainage, area, closets, workshops.

Foundations.—Damp-proof course, dry area, banking of soil against walls. Dryness of basement. Exclusion of ground-air. Ventilation of space beneath ground floor.

Walls.—Materials, thickness. Are party walls carried up to roof? Dilapidations. Evidence of damp at any part; probable source of such damp.

Roof.—Construction. Soundness.

Floors, staircases, windows, doors, ceilings.—Soundness.

Rooms.—Number on each storey, including basement.

Length, breadth, and height. Windows. Total window-space. Space made to open, and whether opening top and bottom. Other means of ventilation. Maintenance of ventilation. Chimney.	of each room.*

Heating arrangements.—Grates, stoves, flues. Hot water or steam system. Boilers, bath-geysers.

Drainage—

Sink wastes Bath wastes Lavatory wastes Floor gullies	Construction and course of waste-pipes. Description and efficiency of traps. Disconnection.

Soil-pipes. Construction, dimensions, position, course, ventilation.

Gullies. Construction and trapping.

Gutters around eaves. Efficiency.

Rain-pipes. Course, trapping, disconnection, destination. Leakage.

House drains. Course, construction, dimensions, gradients, ventilation, means of access (inspection chamber), disconnection from sewer (interceptor). Flushing, cleanliness. Soundness, as tested by smoke, chemical test, or water. Drains under basement.

Cesspool (if any).—Position, construction, dimensions, ventilation, overflow, water tight.

Sanitary conveniences.—Number, position, cleanliness, lighting, ventilation. If outdoor, note distance from nearest door or window. If more than one house using same closet, note the number. State also number of occupants.

W.c., trough-closet, slop-closet, hand-flushed closet. Kind of apparatus, efficiency, source of water supply, sufficiency of flush.

Pail-, pan-, tub-, or box-closet. Size of receptacle, material, floor-level, means of access, with or without ashes or other admixture.

Privy-midden, privy with cesspit, earth-closet. Dimensions of receptacle, relation of floor to ground-level, materials, water-tight, covered, arrangement for applying ashes or earth to excreta. Connexions with sewer.

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* *As regards sleeping-rooms in basement*, or "underground rooms," certain further details are necessary, namely, depth of floor below level of adjoining street; height of room; height of ceiling above footpath or nearest ground adjoining; width, depth, and lateral extent of area in front; depth of drain below floor; position of window in respect to steps (if any) bridging across open area; the conditions as to letting and occupancy.

Household refuse.—Means of storage. Position.

Scavenging.—Mode, frequency, and efficiency of removal of excreta and household refuse. By whom performed.

Water supply.—Public or private, from mains (by tap or stand-pipe), spring, stream, canal, dip-trough, well, rain-water cistern; distance from house, constancy, sufficiency, purity. Note any obvious risk of pollution. If from well, note depth, construction, lining, cover; distance in feet of nearest possible source of pollution, or filth accumulation of any kind. If from cistern, note position, construction, cover, cleanliness, connexion with w.c., discharge of overflow pipe.

Cleanliness of premises.—Light. Ventilation. Cleanliness.

Animals kept.—Description. Number. Where kept. Nuisance resulting.

Inmates.—Number of residents. Age, sex, occupation of each. Number of families; distinguishing tenement occupied by each.

Number sleeping in each room, if there is suspicion of overcrowding. Number sleeping in basement.

Houses vary as to need for inspection according to class and kind. **Private houses** occupied by one family presumably belong to persons of such social position and habits that but little enforcement of sanitation is required. **Houses let in lodgings,** or tenement houses, on the contrary, require a good deal of supervision. Houses of this nature are such as are let out to separate families, living each in a separate occupancy of one or more rooms. There is no common kitchen or common dormitory. Houses let in lodgings are usually subject to special bye-laws under which they are registered and controlled in respect of occupancy, overcrowding, sanitation, periodical cleansing, etc. Not infrequently these houses were built for use as private dwellings, and have become sublet without structural alteration. Under the Customs and Inland Revenue Act of 1890 the landlord of tenement dwellings let at rents not exceeding 7s. 6d. per week may be exempted from inhabited house duty if the medical officer of health of the district certifies the house as sanitarily fit for the purposes to which it is put. By that Act, and by bye-laws for houses let in lodgings, a certain amount of control is exercised.

Common lodging-houses are lodging-houses pure and simple, with living-room, kitchen, and dormitory open to use by all the lodgers, who are not members of the same family, but are isolated persons finding it convenient to lodge together. **Artisans' dwellings,** such as those under the Guinness Trust, the Peabody Trust, etc., are blocks of "model" dwellings, not different in principle from, but better in equipment than, houses let in lodgings. **Stable dwellings** are tenements over stables in "mews." They are objectionable, owing to the occurrence of effluvia arising from stables, manure, etc., and they generally have other defects. **Underground dwellings** are tenements limited to basement rooms, the ceiling of which is not higher than the level of the street.

CHAPTER VII

SCHOOLS AND SCHOOL HYGIENE

BROADLY speaking, school buildings are of two types —(1) that in which the class-rooms are grouped more or less completely around an assembly or "central hall"; (2) that in which the class-rooms are grouped around a corridor, veranda, or quadrangle, independently of an assembly hall, following in some degree a "pavilion" form of structure. The general principles as to site, surroundings, construction, and drainage are, of course, the same for schools as for most other buildings. The cost of school building has increased of late years, and in normal circumstances is about £10 to £14 per head (at 5d. per foot cube), including 10s. to 12s. per head for furnishing and equipment. The Committee on the Cost of School Buildings (1911) reported that reduction in expenditure was practicable by careful attention to small savings on numerous items. The building methods which were proposed to the Committee, in addition to the use of brick and stone, were the adoption of steel frame work (with curtain walls, hollow or solid, of concrete, brick, or patent material, including "frazzi"), reinforced brickwork, ferro-concrete, brick with solid 9-in. walls or thin hollow walls, timber frame, and wooden buildings.

Dimensions.—The Board of Education recommend that no school should ordinarily be built to accommodate more than 1,000 to 1,200 children, in three departments, and no single department should accommodate more than 400 children. For departments of this size a plan formerly adopted was that of a central hall ($3\frac{1}{2}$–4 sq. ft. floor space per scholar) with (about 7) class-rooms grouped round it. Smaller departments may have class-rooms opening from a corridor. For small schools a large room with one or more class-rooms will be sufficient. There should always be at least one class-room, in addition to a large schoolroom, except in special cases.

Where the site is sufficiently large, open and fairly level, the most economical plan is that of a school on the ground floor, and this is preferable for educational reasons. In any case a school building should, preferably, not be on more than two floors.

For older scholars the Board of Education prescribe a minimum of 10 sq. ft. floor-space per scholar (i.e. approximately 120–140 cub. ft.; in army schools 180–200 cub. ft. is allowed); for infants 9 sq. ft., unless there is no corridor or central hall, in which case more than 9 sq. ft. is required. The Board have fixed a standard for higher elementary schools of 15 sq. ft. per scholar if single desks be used, and 12 sq. ft. for dual desks, and for secondary and "special" schools 18 sq. ft. The height of the class-room should be not less than 12 ft.

Special classes. *For handicraft classes, etc.* — Where provision is made for the teaching of cookery, laundry work, handicraft, or special subjects, the Board of Education have prescribed conditions. A cookery or laundry school should accommodate 18 pupils, each having 25 sq. ft. of floor-space. Special arrangements must be made for ventilation, sinks, ranges, stoves, etc. The temperature should not exceed 70° F. Class-rooms for handicraft and for science work should have 30 sq. ft. of floor-space for each scholar. Such schools should have their own lavatory and cloakroom accommodation.

For blind, deaf, and defective children.—Schools for afflicted children should not be held in the same building unless structurally separated. The superficial area of the site should provide not less than 30 sq. ft. per child of open space exclusive of buildings, and not less than 15 sq. ft. of floor-space in the class-rooms, and 18 sq. ft. for physically defective children. Single desks should be provided, and suitable accommodation for manual instruction. Arrangements must be made for easy supervision. In residential schools 500 cub. ft. per child should be provided in the dormitories.

Separate rooms may be provided for school doctor and medical inspection (20 ft. long), and also for school meals (kitchen 200 sq. ft. for 100 meals daily).

Lighting.—Every part and corner of a school should be well lighted, and, as far as possible, from the left side of the scholars; other windows in class-rooms may be regarded as supplementary or for ventilation. Where left light is impossible, right light is next best; direct front light is in no circumstances approved.

Windows should never be provided merely for the sake of external effect. All kinds of glazing which diminish the light and are troublesome to keep clean and in repair must be avoided. A large portion of each window should be made to open for ventilation. The sills of the main lighting windows should be not more than 3½ ft. above the floor; the tops of the windows should as a rule reach nearly to the ceiling; the upper portion may be made to swing (hopper or swivel), or the whole window may open on a central axis. The ordinary rules respecting hospitals should here be remembered. Large spaces between the window heads and ceiling collect foul air.

Skylights are objectionable in schoolrooms or class-rooms. They may be allowed in central halls having ridge or apex ventilation. The colouring of the walls, ceilings (warm white), and fittings, and the size and position of the windows, are especially important in their bearing on the eyesight of the children. For artificial lighting the incandescent gas-burner or electric light is recommended, properly placed and shaded (*see* p. 212). For ordinary school work the minimum illumination at the desk should not fall below 2 foot-candles, 1 foot-candle in assembly room, and 4 foot-candles for special work (art, sewing, etc.). The illumination on the blackboard should be 60 per cent. in excess. In all cases there should be adequate shading to avoid glare. (*See* p. 212.)

Ventilation (*see* p. 192).—Natural ventilation by external windows, fire-places, and extract flues is usually sufficient to maintain the purity of the air in schools, but artificial means, coupled, when necessary, with low-pressure fans, filtration, and warming, may be desirable though not always attainable in practice. About 2,000 cub. ft. of fresh air per head per hour is required, and, to avoid draught, it should enter the room at a rate not exceeding 5 ft. per second. The window area should be fully one-tenth of the floor area and may with advantage be one-fifth, and half the window space must be made to open. When the windows are suitably designed, carried to the ceiling, easily opened at the top, and opposite each other or intelligently used in connexion with two or more warm outlet flues or separate air-chimneys, and there are also large open ventilating fire-grates, stoves, or radiators, by which warmed fresh air is admitted, class-rooms can be both warmed and ventilated adequately and economically. It is well that windows should have both the top and bottom panes arranged to open, the bottom inwards as hoppers, the top as hoppers or swivels. Gratings in floors should not be provided. Besides continuous ventilation, rooms should be flushed with fresh air as often as possible.

In schools in large towns it has sometimes been thought desirable to ventilate by means of the propulsion or **plenum system.** In this case the air must be screened and moistened, and propelled by fan into the main entrance duct. It must also be heated, preferably by steam coils. The system combines heating and ventilation, but it is relatively costly, not always easy to work, and the air lacks some degree of freshness. Moreover, the system has the evil effect of accustoming the children to closed windows.

Warming (*see* p. 207).—The temperature of classrooms should be about 56–60° F. Stoves are only approved by the Board of Education when provided with proper chimneys, supplied with fresh air direct from outside by flues, and not so large as to occupy too much floor space, or of such material as will get red hot. Open fire-places have the great advantage of assisting ventilation as well as providing heat. They should be protected by fire-guards. A thermometer should hang in each room. Low-pressure hot water systems have been recommended for schools. Where adopted 25–30 sq. ft. of direct heating surface should be allowed per 1,000 cub. ft. of capacity.

Desks.—Desks may be classified in three groups: (*a*) the continuous desk with continuous seat or separate seats, (*b*) the dual desk and seat combined, and (*c*) the single desk and seat, adjustable or not adjustable. The ideal is, of course, the single desk of suitable size and character (or adjustable). In elementary schools, however, the most economical arrangement is, perhaps, the continuous desk with separate seats graded according to requirements. This simple arrangement combines the advantages of dual desks without the disadvantages, and may provide for, say, half a dozen places with single pedestal chairs (the "Sheffield System"). Many schools are now fitted with this kind of desk. It is supported on two plain pedestals screwed to the floor. Each seat has a back, and stands on a single pedestal. The advantages are that the seats are isolated, each child is accessible, and can stand by its seat in its place for drill, etc., and schoolrooms cannot be overcrowded as with dual seats or forms. Each seat occupies about 1,000 sq. in.

of space. Cleaning is much simplified with these seats and desks.

The edge of the desk should be vertical, or nearly so, over the front edge of the seat, and about the height of the scholar's elbow; that is to say, the "distance" between the edge of the seat and the desk should be nil or minus, never plus. The seat should be at least 9 in. wide, and about the height of the knee. The desk should slope (15°), and the seat be provided with a back: it is desirable to provide for adjustments of either the seat or the desk, so that they may be separated for writing and for the physical-exercises lesson, and brought together for reading. If a bench or continuous desk is used, 20 in. should be allowed to each pupil (18 in. for infants).

Playground.—The surface of the playgrounds should be levelled and smooth without being slippery, and composed of materials such as asphalt or granolithic cement, which do not form dust. They should be durable and well drained. Some authorities recommend tar-paving. Gravel, cinder-ashes, shingle, and loose materials are unsuitable. A certain portion should be covered in for use in wet weather. The whole playground should be open to the sun, and the school site should be of a size giving at least a quarter of an acre to 200 children, and the playground at least 30 sq. ft. per child. The best shape is square. Playgrounds should be separate for boys and for girls. In towns roof playgrounds may be useful.

Cloak-rooms, other than passages, should be provided where damp garments can be dried. Cloak hooks should be fixed 12 in. apart (18 in. for girls), and gangways between rows of hooks should be not less than 4 ft. wide. Cloak-rooms should be amply lighted and ventilated, with separate means of ingress and egress, and should, where practicable, contain lavatory basins (2 for every 50 children). In many schools in Germany, and in a few schools in this country, **shower-baths** (for bathing 12–20 children at one time) have been instituted with excellent results. The usual type is a rose shower over a shallow bath sunk in the floor or in a separate cell, with or without a separate dressing-box. The water is warmed, and a towel and soap are provided for each child.

Water supply.—All schools should be provided with an adequate supply of wholesome drinking-water. If such supply cannot be obtained from the public mains, care must be taken to ascertain that the supply proposed is adequate, is of suitable character, and is not liable to pollution (*see* pp. 38–57, 93).

The pipes should be so laid as to be protected from frost, and so that in the event of their becoming unsound the water will not be liable to become fouled, or to escape without observation. There should be no direct communication between any pipe or cistern from which water is drawn for domestic purposes, and any water-closet or urinal.

All water-closets and urinals should be provided with proper service cisterns, affording adequate flush. Any cistern should be water-tight, covered and ventilated, and so placed that the interior may be readily inspected and cleansed.

Sanitary conveniences. — Separate arrangements are required for boys and girls, and there should be at least one closet for every 15-25 girls and 25–40 boys (in addition to urinals). Each must be properly lighted and ventilated and have a door (3 in. short at foot and 6 in. at top). They should be disconnected from the school proper by a well-ventilated lobby or covered way. Flush-closets are best adapted for the purpose in some ways, and trough-closets are used in many schools. But, probably, the time has come for schools to be supplied with a sufficient number of some simple form of wash-down closets with separate water waste preventer cisterns or, if necessary, flushing apparatus for half a dozen at one time (p. 299). Dry-earth systems in schools require careful supervision. It is, of course, possible and frequently necessary to make pails or earth-closets serve the purpose in rural districts, but only by constant supervision can they be prevented from becoming a serious nuisance in schools. They should be situated at least 20 ft. from the school premises. Urinals, in proportion of 10 ft. for 100 boys, should be properly constructed of smooth non-absorbent material, and should have a sufficient water supply.

Soil-drains from schools should be made of glazed stoneware pipes (4 to 6 in. diam.), having a fall of 1 in 48 for 4 in. and 1 in 60 for 6 in., and they must be provided with traps, ventilators, and inspection chambers.

School drainage.—The following Memorandum of the Local Government Board on the arrangements for drainage and disposal of waste matters at public elementary schools for which loans under the Board's sanction are required (with special reference to schools in country places where sewers and water services are not available) was issued in 1913 :—

At a school, even where no one resides on the premises, provision will have to be made for the disposal and removal of the following matters: (1) Excremental matters; (2) ashes and other dry refuse; (3) waste water, as from lavatories and floor washing; (4) surface-water from roofs, yards, etc. The best means for disposing of these several matters will vary in different cases according to facilities of drainage and water supply and other local conditions, and in choosing the most suitable arrangements careful regard will have to be paid to the circumstances of each case.

WATER-CLOSETS

Where an efficient system of public sewers and a constant water supply under pressure are available, water-closets should be provided and their contents conveyed into the public sewers by drains, which should also receive the liquid waste from urinals, lavatories, and sinks, and, where permitted, the surface-water. Water-closets should be of a suitable and efficient type, with adequate separate flushing arrangements for each closet.

Where a water supply for flushing is available but there are no sewers, if water-closets are adopted they should be drained into a water-tight tank with an overflow discharging on to an efficient filter or a suitable area of land for irrigation, or into a water-tight cesspool without overflow, which should be so arranged that the contents can be readily removed by means of a suitable pump into a tank cart, or by some other efficient method. In no case can disposal of sewage by subsoil irrigation or any system of leakage into the subsoil or by its discharge untreated into a ditch or watercourse be regarded as satisfactory. Where drainage is into a tank or cesspool, rain-water should be excluded from the sewage with a view to lessen its volume, and, in the case of a cesspool, to avoid the need for frequent emptying.

Where sewers are available but no supply of water is laid on for flushing, it will generally be best to adopt some form of dry closet as described hereafter. Hand-flushed water-closets do not work satisfactorily.

EARTH-CLOSETS

Where neither sewers nor water service are available, as is often the case in small villages, some form of dry closet will be necessary. The closets may be furnished with movable receptacles (pail closets) or with small fixed receptacles on the lines set out in the Board's Model Bye-laws with respect to New Buildings in Rural Districts, i.e. the receptacle should be of small capacity and water-tight construction with bottom at least 3 in. above the level of the ground, and with arrangements to facilitate the application of dry earth or other absorbent and the removal of the contents. Privies with large deep pits or open middens cannot be approved.

The contents of the closets should be kept dry by excluding rainfall and, as far as practicable, all other liquid, and by the use of a suitable absorbent, which will be especially needed in the girls' closets. The absorbent may be dry earth, ashes, sawdust, peat dust, or road sweepings dried and sifted. (The ashes produced at a school are not usually sufficient in quantity alone, and there are none in summer.) A shed or other suitable accommodation should be set apart for the drying and storage of the absorbent.

Arrangements will have to be made for the supply and application of the absorbent, and for the frequent periodical removal and disposal of the contents of the closets.[*]

WASTE WATER

Even where dry closets are provided and rain-water is separately dealt with, there will still be need for some means of disposing of foul waste liquids, as from urinals, sinks, lavatory basins, and wash pails. If sewers are not available these liquids may be taken by drains to a filter or irrigation area, or into a small cesspool constructed as already mentioned. In some instances, where there is no ground belonging to the school sufficient for the placing of a tank or cesspool, it may be necessary to use movable receptacles for the reception of waste liquids from lavatories, urinals, etc., the receptacle for urine being filled with some absorbent such as sawdust. Such expedients, of course, require constant attention—at least daily—if nuisance is to be avoided; and in the case of new schools, and, where possible, in all other cases, sufficient ground should be provided to render resort to them unnecessary.

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[*] The following arrangement of earth-closets has been found to work satisfactorily at some rural schools: At the back of the range of closets is a covered "earth chamber," extending the whole length of the range and measuring some 7 ft. from front to back. At the back the chamber is partially divided by a dwarf wall into two compartments—one for dry and the other for used earth—leaving space for a gangway between these compartments and the backs of the closets. In front the floor of the earth chamber is continued into the space under the closet seats with a slope towards the centre of the chamber. The space under the seats is open at the back for its full width to the earth chamber. Down the gangway runs a channel for urine which discharges into a small tank: this channel and tank are filled with peat moss or sawdust to absorb the urine; when the absorbent is saturated it has to be removed, and fresh material substituted.

The mode of use is as follows: One or more loads of dry earth are placed in one of the compartments, and a layer of this earth 6 in. deep is spread on the floor under each closet seat, so as to receive the excreta upon it. Once a week, conveniently on Saturdays, the fæcal matter is covered up with a fresh layer of the earth until in course of time the heap reaches a depth of about 2 ft. It is then removed to the empty compartment to dry, and a fresh layer of earth is spread under the seats. This process is repeated until all the earth has been shifted to the other compartment. It is then worked back again in like manner, using first the portions of earth which have been drying longest. When this process is properly carried out it has been found that fæces and paper are inoffensively disintegrated by the action of the earth with its contained organisms, and that the same earth can be used over and over again without the need for addition or removal.

Where this system is adopted, careful attention must be given to the following points: 1. Impervious materials must be used in all places where earth or fæcal matter is liable to come in contact with the structure. Wood should not be used. 2. The earth chamber should be properly roofed to exclude rainfall, and well ventilated. Its floor should not be below the ground level. 3. All urine should be conveyed away from the earth chamber, received in an absorbent, and removed. 4. Suitable dry earth should be used, preferably top soil from a field or garden "in good heart." Ashes are unsuitable. 5. Careful and intelligent attention must be paid to the working of the closets by a person specially detailed for this purpose, and the earth must be shifted and redistributed at least once a week; it must not be allowed to get saturated with liquid. A door for access to the earth chamber will be needed, but should be kept locked when not in use.

Where there is no public water service, rain-water from the roofs may often be usefully collected for washing purposes, being softer than well water. Where not so collected, if there is no sewer into which to take it, it should be excluded from the sewage, and may be discharged in any convenient method, as into a ditch or watercourse, or, where the soil is porous, into a soakaway pit at a sufficient distance from the building so as not to cause dampness of the foundations.

Where possible, it is desirable that the sewage from the schoolmaster's house should be dealt with by the same system as that from the school buildings, but where this is not feasible one or other of the methods for the disposal of excretal matters and liquid waste already mentioned should be adopted.

Where sewers and public water service are not available, it is desirable that there should be in connexion with the house plenty of garden ground on which to dispose of refuse matters.

GENERAL

In connexion with the drainage and sanitary arrangements for schools, the following points should receive special attention :—

The drainage and closet arrangements should be planned on the general lines embodied in the Model Bye-laws of the L.G.B.

Drains.—The drains for foul water should be laid in straight lines between inspection chambers, and so as to be quite water-tight; they should be properly ventilated and be disconnected, by means of a trap in an inspection chamber, from any cesspool or covered tank into which they discharge. Should a drain have unavoidably to be laid near a well or other source of water supply, the drain, if of stoneware pipes, should be surrounded with cement concrete at least 6 in. in thickness: or should be of cast-iron pipes with lead joints. It is desirable that pipes of 4 in. diameter should have a fall of not less than 1 in 48, and 6-in. pipes of not less than 1 in 60.

Cesspools and tanks should have walls and floors so constructed as to be quite water-tight (this also applies to the floors of filters and so much of their external walls as are below the surface of the ground). They should be not less than 50 ft. distant from the school or from any dwelling-house, and should be as far as possible from any well or other underground source of drinking-water which might be in danger of being polluted by leakage. The sewage disposal works should be fenced in so that they cannot be interfered with by the children.

Cesspools and covered tanks should be properly ventilated and provided with a suitable pump, and should be in positions conveniently accessible by a tank cart for the purpose of emptying.

The capacity of tanks which overflow on to a filter-bed or irrigation area need not exceed from one to two days' volume of sewage;* but cesspools which have to be emptied from time to time should be of larger capacity. Filter-beds should be not less than 2 ft. 6 in. in depth, and the filtering medium should consist of some hard and clean material, care being taken that the liquid is evenly distributed over the surface of the filter-bed by a suitable apparatus. Filters should in all cases have free outlets, so as to drain the whole of the filtering media If no land treatment is provided, the area of the filter-bed should be sufficient to deal with the liquid at a rate not exceeding 40 gallons per sq. yd. per day for a filter 2 ft. 6 in. deep, or at a proportionately greater rate for deeper filter. When subsequent land treatment of the effluent is adopted, a rate of filtration twice as rapid as the above may be allowed.

Irrigation areas.—Land for irrigation should have an adequate area and suitable soil, and should be at a sufficient distance from any inhabited building or sources of water supply, so as not to create a nuisance or to pollute the water. The nature of the soil should be stated in the application.

Land.—Where land outside the school premises is required for tanks, filter-beds, irrigation, etc., its use should be secured by a definite legal agreement, and if the works are to be carried out by means of a loan the land should be purchased or leased, the purchase or lease to be conditional on the Board's sanction being obtained to the loan.

Need for supervision.—It is very important that the sanitary arrangements of schools should be kept in a cleanly and proper condition, not only for the sake of the health of the children while at school, but also as an object lesson in-cleanliness which they may carry into practice in their own homes. But this cleanly condition cannot be maintained without supervision. It may be necessary to employ an efficient attendant to see to the cleanly keeping of the sanitary conveniences as well as of the school premises generally. This will be especially necessary at schools where, in the absence of sewers and water service, methods have to be adopted which involve hand removal. Thus, where dry closets are adopted, it will be necessary to appoint someone to supply absorbents, to empty the closets at frequent and regular intervals—say every Saturday, or oftener if necessary—and to remove the contents to a suitable place of deposit. Where a cesspool is used the contents will have to be pumped out from time to time and distributed over land in a proper situation. Filter-beds and irrigation areas will also need supervision from time to time to keep them in proper working order.

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* This may generally be assumed at 2½ gallons per head of the accommodation provided (including teachers) at the school if w.c.s are used, or at 1 gallon per head where only urine and slop-water have to be dealt with.

Schools and infectious disease.—The following is the Memorandum on this subject issued jointly by the Local Government Board and the Board of Education, 1909:—

PART I.—INTRODUCTORY AND GENERAL

1. School hygiene has been placed upon an altered footing by section 13 of the Education (Administrative Provisions) Act, 1907; and the introduction of the School Medical Officer (**S. M. O.**) into the local administrative machinery of preventive medicine has been accompanied in the Code of Regulations for Public Elementary Schools (1909) by new or modified provisions as to medical inspection, and as to the closure of schools and the exclusion of individual scholars with a view to the prevention of the spread of disease.

As will be seen from a consideration of this Memorandum, the recent changes have materially increased the possibilities of effective action against disease possessed by local authorities and their medical officers.

CODE REQUIREMENTS FOR SCHOOL CLOSURE AND FOR THE EXCLUSION OF INDIVIDUAL SCHOLARS

School Closure

2. The Code for 1909 contemplates that in certain particulars new administrative conditions shall be satisfied before the Board of Education will allow a claim for grant in respect of schools which, owing to closure with a view to preventing the spread of disease, have not been open the requisite number of times.

This closure may be compelled by the **S.A.** under Article 57 of the Code, or may be voluntary on the part of the Local Education Authority. Article 57 is as follows: If the **S.A.** of the district in which the school is situated, or any two members thereof, acting on the advice of the **M.O.H.**, require either the closure of the school or any department thereof, or the exclusion of certain children for a specified time, with a view to preventing the spread of disease or any danger to health likely to arise from the condition of the school, such requirement must at once be complied with.

As regards the grant, provision is made by Article 45 (*b*) where a school is compulsorily closed or is closed under the advice or with the approval of the **S.M.O.**, or for any other unavoidable cause. It runs as follows: If the requisite number of meetings has not been held owing to a closure of the school under Article 57, or under the advice or with the approval of the **S.M.O.**, or for any other unavoidable cause, the grant will be paid in full, provided that the requirements of this Article are satisfied after an allowance of nine meetings has been made for each week of such closure.

Exclusion of Children

If the **S.A.** or two members thereof, acting on the advice of the **M.O.H.**, require the exclusion of certain children for a specified time in order to prevent the spread of disease, those children must be excluded (Article 57). Thus the **M.O.H.** can initiate a compulsory process whether for closing the school or for excluding scholars, though he can only do so through the **S.A.** or two members thereof.

The exclusion of children is also provided for on the authorization of the **S.M.O.** by Article 53 (*b*) of the Code, which is as follows: Where the Board (of Education) are satisfied (i.) that proper arrangements have been made by the Local Education Authority for enabling the **S.M.O.** to ascertain and certify cases in which the exclusion of children from school is desirable, and (ii.) that the **S.M.O.** has authorized the exclusion of certain children from the school (1) on the ground that their exclusion is desirable to prevent the spread of disease, or (2) on the ground that their uncleanly or verminous condition is detrimental to the other scholars, or (3) on the ground that, owing to their state of health or their physical or mental defects, they are incapable of receiving proper benefit from the instruction in the school, the exclusion of such children shall be deemed for the purposes of this Code to be exclusion on reasonable grounds.

For the purposes of this provision the Local Education Authority may direct that no children who have been excluded under the authority of the **S.M.O.** or under Article 57, or who have been absent from school owing to sickness, shall be re-admitted to school if the **S.M.O.** is not satisfied that they can attend school without risk to themselves or others.

Every direction or authority given by the **S.M.O.** must be embodied in a certificate signed by him. A copy of every certificate must be furnished to the Local Education Authority and must be produced, if required, to any Inspector or Officer of the Board's Medical Department.*

3. The general effect of the changes which these Articles of the Code bring about may be stated as follows:—

(*a*) Henceforth there is no appeal against requirements of the Sanitary Authority made in accordance with the terms of Article 57.

(*b*) Under previous Codes the requirements of the Article corresponding to Article 45 (*b*) have been satisfied when a school has been closed voluntarily "under medical authority," including the advice or approval of any medical practitioner. Under the present Code, where closure for medical reasons has been effected voluntarily, the requirements of Article 45 (*b*) will not be satisfied unless the **S.M.O.** recognized by the Board of Education has advised or, where he has not advised, approves the closure.

(*c*) In practice it is customary for the **M.O.H.**, without resorting to the formal procedure of Article 57, to arrange, as soon as an infectious case is notified to him, for the temporary exclusion from school of the infected child and of any children who have been in contact with the infectious case, or of any children suspected of being themselves infectious. If such exclusions are to be deemed to be on "reasonable grounds" they must, in accordance with Article 53 (*b*), be endorsed at the time or subsequently by the **S.M.O.** In previous Codes exclusion on any medical authority has been regarded as "reasonable ground" for exclusion. The new conditions indicate the desirability of a working arrangement between the **M.O.H.** and the **S.M.O.**, when these officers are not the same person, in order that the former may not need to adopt the procedure provided in Article 57 for the formal and compulsory exclusion of individual scholars.

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* For the purposes of the Code "School Medical Officer" means a medical officer named by the Local Education Authority, and recognized as such by the Board of Education. In exceptional cases the Board of Education will recognize separate School Medical Officers for separate parts of one area.

Co-ordination of Work of Medical Officer of Health and of the School Medical Officer and other School Officers

4. It is the desire alike of the Local Government Board and of the Board of Education that the relations of the local **S.A.** and of the Local Education Authority should in all respects be intimate and cordial, in order that the administrative procedures of both bodies may be reciprocally beneficial. It is only by such mutual co-operation that the best interests of each district can be secured to the fullest extent.

5. It must, however, be borne in mind that the **M.O.H.**, acting under the **S.A.**, is responsible for dealing with outbreaks of infectious disease, including such outbreaks in schools; and the action of the **S.M.O.**, where he is not also **M.O.H.**, must be consistent with this general consideration. The importance of this consideration is indicated by the fact that the statutory powers as to isolation of patients and cleansing and disinfection of houses are possessed by **S.A.** alone. The new requirements of the Code in no way diminish the responsibility of the **M.O.H.** for taking all such steps as are demanded in the public interest to prevent the spread of infection. As a matter of administrative educational procedure the certificate of the **S.M.O.** is required under Article 53 (*b*) for cases of exclusion, and for voluntary closure of a school for infectious disease under Article 45 (*b*); but the **M.O.H.** must be in a position to act promptly in each instance, more particularly in regard to exclusion. Cases may frequently occur where prompt action is essential, and where valuable time would be lost by reference either to the **S.A.**, with a view to the issue of requisitions under Article 57, or to the **S.M.O.**; and it is eminently desirable that in these cases, more especially as regards the exclusion of individual scholars, the **M.O.H.** should be in a position to take immediate action.

6. This end can best be secured, in cases where the **M.O.H.** is not himself the **S.M.O.**, by the establishment of definite working arrangements between these two officers under which, on the one hand, Local Education Authorities will authorize managers and teachers to act, as in the past, on the recommendations of the **M.O.H.**, and, on the other hand, the **S.A.** will arrange that the **M.O.H.** embodies his recommendations in certificates which are transmitted to the **S.M.O.** with a view to the formal authorization required by Article 53 (*b*) of the Code in cases of exclusion, and to the approval required by Article 45 (*b*) in cases of closure. Where such working arrangements are adopted, it should seldom be necessary under the new

conditions for the **M.O.H.** to advise the **S.A.**, or two members thereof, to put into force the powers conferred upon them by Article 57 of the Code.

7. The conditions under which mutual co-operation between officers of the local **S.A.** and of the Local Education Authority can be made most effective will vary according to local organization. When in autonomous areas the **M.O.H.** and the **S.M.O.** are the same officer, direct unity of action is at once obtained. In all other cases waste of effort and some duplication of work can only be avoided by agreement between the two officers and their authorities on general lines of action, both as to the details of medical administration and as to the regulations for teachers and other school officers mentioned in paragraph 9.

In county areas, where the County **M.O.H.** is also the **S.M.O.**, he is in a position to organize the needed co-operation. Where, however, these offices are held by different persons, or where there is no County **M.O.H.**, it is obviously desirable that definite arrangements should be made between the Local Education Authority and the Local **S.A.** providing for the harmonious co-operation of their respective officers. When Assistant **S.M.O.** are not themselves the District **M.O.H.** the need for frequent interchange of information between the officers of the Sanitary and Education Authorities will arise; and lines of action in regard to closure of schools and the exclusion of individual scholars will need to be settled with due reference to the particular circumstances of the area, and to the regulations adopted by the Local Education Authority for the organization of the **S.M.S.**

8. In order that the requirements of Article 53 (*b*) of the Code may be met, it is necessary that all cases of exclusion from school by the direction of the **M.O.H.** should be promptly reported by that officer to the **S.M.O.** As a rule closure of the school should only be arranged in consultation with the **S.M.O.** This rule should be followed, save in serious emergency; and when immediate closure is necessary in the interests of public health, the **M.O.H.** should at once communicate with the **S.M.O.**

9. Efficiency in the prevention of the spread of infection implies active co-operation not only between the **M.O.H.** and the **S.M.O.**, but also between these officers and the school teachers, school nurses, and attendance officers. This general need can be met by each Local Education Authority making regulations as to the duties of each of their officers to send forthwith to the **M.O.H.** and to the **S.M.O.** information regarding any children suspected to be suffering from infectious

illness, and to exclude such children temporarily. This point is emphasized in the following recommendation quoted from Circular 596 issued by the Board of Education on 19th of August, 1908 :—

> He (the **S.M.O.**) must so organize his machinery that both he and the **S.A.** shall receive immediate information of any such occurrence (of infectious disease), whether the disease is notifiable or not, by duplicate notices or otherwise, so that the matter may be dealt with effectively and without confusion at the earliest possible moment. Definite regulations should be made for this purpose.

It is expected that such regulations defining the circumstances in which teachers and other school officers should notify suspected cases of infectious disease to the **M.O.H.** and to the **S.M.O.** will be made generally by Local Education Authorities.

PART II.—PRINCIPLES OF ACTION

INFORMATION AS TO NOTIFIABLE DISEASES

10. Success in the control of infection depends on the completeness and promptitude with which each case of infectious disease is recognized, and the completeness and promptitude of the action taken on this information. In this and the following eight paragraphs the means of obtaining such complete and prompt information are considered. All known cases of the diseases coming within the scope of the Infectious Disease (Notification) Acts or of Section 55 of the Public Health (London) Act are notified to the **M.O.H.** Measles, scarlet fever, and diphtheria are the most common diseases affecting school children which are thus notifiable. Whooping-cough, which is prevalent among school children, does not in the majority of sanitary districts come within the scope of the Notification Acts, though it can be added by resolution of the **S.A.** subject to the approval of the **L.G.B.**

Investigation of "Missed Cases

11. In the administrative control of such notifiable diseases, therefore, action must start with the **M.O.H.** In a well-organized and efficiently worked sanitary district each notification by a medical practitioner of a case of one of the notifiable diseases should form the starting-point for a prompt and full investigation of the possibilities of infection. As stated in

Article 18 (2) of the Local Government Board's Regulations as to **M.O.H.**, it is the duty of the **M.O.H.** "to inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within his district"; and with this object in view he will regard each case of notified disease as possibly connected with other cases of the same disease, which, owing to their mildness, or the absence of some of the characteristic symptoms, have been overlooked by the parent, or the teacher, or both. The investigation of such missed cases is indispensable to effective administration. A portion of this investigation may need to be undertaken at the patient's home: it is incomplete unless an equally thorough inquiry has been made into the condition of the children who have been in contact at school with the scholar who has fallen ill. This inquiry should be shared by the **M.O.H.** and the **S.M.O.**, if these offices are not held by the same official. It should include the recent history and present condition of children who have recently returned to school after an interval of absence, and be followed by careful watching of the children who have been in contact with the infectious case.

Instructions to Teachers and Parents

12. It is in connexion with these investigations that the co-operation of teachers and parents is needed, as well as of the **S.M.O.** whenever the latter can help in this work. Infection is often spread in school by the attendance of children suffering from initial and unrecognized symptoms, or attending school in the convalescent stage, or throughout the course of a mild attack of an infectious disease. To minimize the danger, the teacher should be instructed in the symptoms of onset of the chief infectious diseases, and the symptoms which may be manifested by children who have recently passed through the acute stages of these diseases. Clear directions should be given by Local Education Authorities instructing teachers temporarily to exclude children showing any symptom suggestive of any of these diseases, until medical assurance can be had that they may attend school without harm to themselves or danger to other scholars. Instructions of this kind will naturally find a place in the arrangements required by Article 53 (*b*) of the Code for enabling the **S.M.O.** to ascertain and certify cases in which exclusion is desirable. During the prevalence of any particular infectious disease the attention of the teacher may be drawn, by circular letter or otherwise, to the most obvious symptoms indicating the possibility that a scholar is sickening for, or is suffering or recovering from, this disease.

Intimations by School Officers to Medical Officer of Health and School Medical Officer

13. Under regulations framed as suggested in paragraph 9, or apart from such regulations, the school teacher and school attendance officer should inform both the **M.O.H.** and the **S.M.O.** of any children who have recently been kept at home with illness of a suspicious character, or concerning whom circumstances suggest the possibility of infection. This information probably will have come to the teacher and to the attendance officers from direct communication with parents. In some instances the attendance officers and in others the teachers may obtain the earliest information; and the system of intimations to the medical officers should be so arranged as to secure the simultaneous conveyance to the **M.O.H.** and to the **S.M.O.** of such information. No harm can come from duplication of such notifications, and the Local Education Authority can by careful organization devise arrangements which shall be prompt and effective and at the same time easy in application.

14. Opportunity should be taken by circular letters or otherwise to impress upon parents their responsibility in preventing the spread of infection in schools, especially when any special disease threatens to become prevalent. The particular attention of parents should be drawn to the fact that a "bad cold" or an "ulcerated throat" or a "spring rash" may, in fact, indicate a mild attack of diphtheria or scarlet fever, and that to send children to school either so suffering or when convalescing from such conditions, without having first obtained a medical opinion, may involve serious consequences to other children.

Occasional Diagnosis by Medical Officer of Health

15. The difficulty occasionally arises that the parents of a child who is suspected to be suffering from a mild attack of an infectious disease cannot afford to send, or will not send, for a doctor, although they have kept the child away from school for a few days. Exclusion from school must be continued in these, as in all cases of suspicion, until doubt as to the nature of the case has been removed; and meanwhile the parent must be pressed to utilize the private or public agencies available for medical diagnosis according to circumstances. In such cases, if delay and consequent danger of spread of infection are to be avoided, the **M.O.H.** or the **S.M.O.**, or some other medical man temporarily or permanently acting for the **S.A.**, should make or aid in making a diagnosis. This corresponds to the general practice in investigating outbreaks of smallpox; and its more frequent adoption for other infectious diseases would

enable local authorities to make better use of their isolation hospitals and other official machinery for preventing the spread of disease.

Intimations by Medical Officer of Health to School Medical Officer and Head Teacher

16. The information as to notifiable infectious cases among school children obtained by the **M.O.H.** should be promptly transmitted to the **S.M.O.** and to the Head Teacher of the school concerned in order that the necessary instructions as to exclusion from school, etc., may be given. In the Metropolis, under Section 55 (4) of the Public Health (London) Act, 1891, it is compulsory on the **M.O.H.** to send a copy of each notification certificate within twelve hours after its receipt to the Head Teacher of the school attended by the patient (if a child), or by any child who is an inmate of the same house as the patient. In sanitary districts outside the Metropolis similar intimations should be sent promptly both to the **S.M.O.** and to the Head Teacher. The notice thus sent to the teacher may also usefully comprise general information on the symptoms of infectious diseases.

INFORMATION AS TO THE NON-NOTIFIABLE DISEASES

17. Whooping-cough, mumps, chickenpox, and infectious diseases other than measles, scarlet fever, and diphtheria which prevail among school children, are seldom added by **S.A.s** to the schedule of compulsorily notifiable diseases. Even in districts in which any of these diseases are notifiable, the parents commonly either do not consult a doctor, or they call him in after secondary infection of other children has already occurred. Hence the **M.O.H.** is dependent for information on the **S.M.O.** and on parents, teachers, and attendance officers; and if the rapid spread of these diseases in school and the need for exclusion from school on a large scale or for school closure are to be avoided, school officers and parents should furnish this information to the **M.O.H.** Prompt and complete notification to the **M.O.H.** and to the **S.M.O.** of such "minor" cases of infectious disease is difficult to ensure; but the appropriate action of Local Education Authorities on the recommendation contained in paragraph 7 (*c*) of the Board of Education Circular 596, dated 17th August, 1908, will, it is hoped, go far towards securing this end. (*See* paragraph 9, *ante.*)

Intimations as to Cases of Doubtful Nature

18. Apart from systematic and prompt intimation to the medical officers by teachers and attendance officers of all cases of the non-notifiable infectious diseases ascertained by them,

further intimations should be sent by them of the absence from school of any child on the suspicion that it is suffering from an infectious disease; and absence of several children of one family from school at the same time, no matter what name be given to the complaint that keeps them at home, should also be reported. In practice it has been found that such intimation of absentees has materially aided the **M.O.H.** in taking measures for the suppression of infectious disease.

19. The medical inspections carried out under the Education (Administrative Provisions) Act of 1907 will in due course enable the medical history of each scholar in respect of infectious diseases to be recorded; and the knowledge thus secured will in the future be valuable in determining whether in particular cases children need to be excluded from school or classes need to be closed when an outbreak of infectious disease occurs. It is anticipated that this information will be valuable, especially in dealing with outbreaks of measles.

It is possible that, in the light of these records and of further work under the new statutory and administrative conditions, some modification of the rules for exclusion and closure given in paragraphs 37 to 54 may be indicated.

GENERAL CONSIDERATIONS AS TO THE ACTION TO BE TAKEN IN RESPECT OF INFECTIOUS DISEASES OCCURRING AMONG SCHOOL CHILDREN

20. There is little doubt that infection in schools is spread to a much greater extent by infectious persons than by infected things; and that by systematically obtaining the information as to the infectious cases indicated in paragraphs 10 to 19, and by adopting the measures of exclusion of patients and of recent "contacts" with them which are described in paragraphs 37 to 55, the common sources of infection can be controlled.

21. Subject to this chief consideration, certain other administrative lines of action may be here indicated. Disinfection of special class-rooms or of particular articles should be undertaken when there is reason to believe that these have been infected. A special caution may be given as to the risk arising from moistening slates with saliva, or from the use in common of penholders and pencils which are apt to be put in the mouth: and steps should be taken to avoid this.

22. The frequent and thorough washing of class-rooms and cloak-rooms is an efficient means of removing both dust and infection. Dry sweeping, on the other hand, tends to scatter dust.

23. Much can be done to prevent the spread of infection by due attention to the sanitation and ventilation of schoolrooms

and cloakrooms; and, so far as practicable, by preventing children having to sit in school in wet clothes or with wet feet. Overcrowding greatly favours the spread of infection, while adequate means of ventilation kept in constant effective use diminish it. The water supply of the school should be pure; and lavatories and closets should be kept in a satisfactory state.

i. *Exclusion of Individual Children*

24. It may be laid down as a general principle that all children suffering from any dangerous infectious disease (i.e of a nature dangerous to some of the persons attacked by it, however mild in other cases) should be excluded from school until there is reason to believe that they have ceased to be in an infectious condition (*see* section 126 of the Public Health Act, 1875, also section 57 of the Public Health Acts Amendment Acts, 1907; the latter section may be put in force in any district by order of the **L.G.B.**).

Furthermore, as it is seldom possible to provide effectual separation of the sick from the healthy within the homes of children attending public elementary schools, it is often necessary that all children of an infected household should be excluded from school: first, because otherwise such children, if unprotected by a previous attack, might attend school while suffering from the disease in a latent form or at an unrecognized stage; and secondly, because it is known that infection of certain diseases may attach itself to, and be conveyed by, the throat secretions or the clothes of a person living in an infected dwelling, even though the person himself remain unaffected. The same considerations will sometimes make it desirable to prohibit the attendance at school of children who are known to have been in contact with a source of infection; of children of certain ages or classes; or of children from a particular street or hamlet.

25. The mode of procedure as regards recognized disease will depend on the natural history of the disease concerned. Patients themselves must not be allowed to attend school (*a*) until free from infection, and (*b*) until such disinfection of the house and of the patient's apparel as may be necessary has been secured. It is impossible to state exactly when personal infection ceases, and the **M.O.H.** must not assume that at the end of the ordinary period of isolation danger to others has, without doubt, entirely ceased. It has ceased in the majority of instances; but in a minority of cases—for instance of scarlet fever and of diphtheria, whether treated at home or in an isolation hospital—the child remains infectious

for a much more protracted period; and in practical administration this possibility must be borne in mind and allowed for.

26. The action with regard to healthy children in the same household as the patient will vary in different instances. The usual procedure is to allow their return to school at an interval after the removal or complete recovery of the patient and disinfection of the house a little longer than the maximum known period of incubation of the disease in question. In view of the occurrence of slight overlooked cases and of "carrier" cases of infection, it is often advisable to prolong to a certain extent, as indicated hereafter, this period of exclusion from school.

27. Exclusion from school of the children of infected households most often fails as a means of preventing spread of infection because there are undiscovered or unrecognized cases or carriers of infection; and its failure points to the continued attendance at school of children having recently had attacks of the prevalent disease in a mild or unrecognized form, or who without themselves being ill are carriers of infection. Such unrecognized cases are to be sought especially among (*a*) children attending school from the same street or vicinity as the recognized patients; (*b*) children in the same class; and especially (*c*) children who, on reference to the school register, are found to have returned to school after a short absence.

Although the provision will probably be more useful in private schools, attention may be drawn to section 58 of the Public Health Acts Amendment Act, 1907, which, in districts in which it has been put in force, enables lists of scholars, in a school in which any scholar is suffering from an infectious disease, to be obtained.

ii. *School Closure*

28. School closure is occasionally necessary on account of infectious sickness in the teacher's family involving risk to the scholars. It is also occasionally necessary to close a school or division for one or two days in order that it may be disinfected and cleansed after children suffering from infectious disease have been in attendance, or to allow of the rectification of sanitary defects of a nature likely to contribute to outbreaks of disease.

29. But, in the absence of such special and exceptional reasons for closure, it should not often be necessary to close the school in the interests of public health, if the power to exclude individual children be used to the best advantage. It is only when this less comprehensive but more discrimi-

nating and often sufficient action has failed or, owing to imperfect co-operation between the public health and the school authorities, cannot be applied to the necessary extent, that the question of advising the **S.A.** to require the closure of the school in the interests of public health can arise.

30. It must be remembered that the closure of the school will deprive the **M.O.H.** and the **S.M.O.** of information respecting attacks in their early stage or illness of doubtful nature which would otherwise be obtainable, and in any circumstance will interfere seriously with the education of the scholars. Closure, therefore, should be advised by the **M.O.H.** only in circumstances involving imminent risk of an epidemic, and not then as a matter of routine nor unless there be a clear prospect of preventing the spread of infection such as cannot be expected from less comprehensive action.

31. School closure is more likely to aid in preventing the spread of disease in scattered rural districts than in towns, owing to the fewer opportunities which exist in the former for intercourse between the children of different households elsewhere than at school.

It has also to be borne in mind that in such scattered rural districts means of isolation and of tracing doubtful cases are less effective. Hence school closure is likely to continue to be needed somewhat more frequently in such districts than in towns.

32. In places where there are several public elementary schools, if an outbreak of infectious disease be confined to the scholars of one particular school, it may be sufficient to close that school only, and even where school closure is deemed necessary in the case of a particular school it need not always extend to the whole school or department, but may on suitable occasions be limited to particular classes or departments.*

33. On the other hand, where different schools have all appeared to aid in the spread of disease, though perhaps to an unequal extent, it may be considered advisable that all should be closed, lest children in an infectious state, who previously attended the schools that are closed, should be sent to others that might remain open. There is, however, less likelihood than heretofore that such attendance will be permitted, and a general closure on this ground will seldom be needed.

34. Playgrounds should not remain open when schools are

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* It is to be understood that the exclusion of all the children in a particular class in a department or school, leaving the other children in the department or school free to attend school, is not for the purposes of Article 45 (*b*) of the Code "closure" of the department or school, and that the provisions of that Article do not apply in such cases.

closed, as they provide a meeting-place for the children whom it is the object of the closure to keep apart.

35. It may be laid down as a general principle that closure of a school or of a particular class is justified when the general evidence points to this school or class as the source of infection, and when cases of an infectious disease continue to occur in this class or school after every effort to discover the infecting cases has been made. The degree of application of this principle to special cases is discussed later.

36. But while the **M.O.H.**, in deciding whether to advise the **S.A.** to require the closure of a public elementary school,* will be guided mainly by the consideration how best to check the spread of disease, other considerations may require also to be taken into account by the **S.M.O.** in deciding whether to advise or to approve action taken voluntarily under Article 45 (*b*) of the Code.

School attendance may be greatly lowered during the prevalence of an infectious disease, especially of measles and whooping-cough, and school closure may then be desired to avoid a considerable reduction in the average attendance. In such circumstances a large proportion of susceptible children have generally already contracted the disease or been exposed to infection, and the closure of the school commonly does little to prevent further spread of the disease. Closure by the **S.A.** under Article 57 of the Code is contemplated solely in the interests of public health, and apart from this consideration the **M.O.H.** is not justified in advising closure to prevent financial loss to the Local Education Authority.

The question of closure, when that step is not clearly necessary to prevent the spread of disease, should therefore be left to the voluntary action of the Local Education Authority, advised by the **S.M.O.** if he is not himself **M.O.H.** That officer, however, before advising or approving closure, should confer with the **M.O.H.** on the public health aspects of the proposed closure.

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* Sanitary Authorities have no general power in respect of Sunday schools, or other private schools, except in so far as these may contravene section 91 (5), section 126, or other provision of the Public Health Act, 1875, but it will often be expedient to invite the co-operation of managers of such schools in efforts for securing the public health. Experience shows that they are usually ready to defer to the representations of the authority responsible for the public health of the district.

If, however, the **L.G.B.**, on the application of the Local Authority, have declared sections 57 and 58 of the Public Health Acts Amendment Act, 1907, to be in force in the district, the **M.O.H.** will have power to require a child who is or has been suffering from infectious disease, or has been exposed to infection, to be excluded from school until the **M.O.** has certified that the child may attend school without undue risk of communicating such disease to others (section 57). The power given to the **S.A.** by section 58 to obtain a complete list of the names and addresses of day scholars in schools in which any scholar is suffering from infectious disease may be useful to the **M.O.H.** in his investigation of the causes of outbreaks if he finds it necessary to extend his inquiry to private schools.

PART III.—RULES FOR ACTION IN RESPECT OF PARTICULAR DISEASES AND RULES OF OFFICIAL PROCEDURE

37. The diseases for the prevention of which the exclusion of particular children from school or school closure may be required are principally those which spread by infection directly from person to person, such as measles, whooping-cough, scarlet fever, diphtheria, epidemic influenza, smallpox, and rötheln (German measles). In rare cases the same measures may be necessary for enteric fever and diarrhoeal diseases, when these spread through the agency of local conditions, such as infected school privies.

38. In the light of the general principles already set out the following procedure appears to be indicated in order to enable the **M.O.H.** or the **S.M.O.** to advise as to the minimum duration of exclusion of school children which can with reasonable safety be adopted in the several more common infectious diseases.* It should be noted that although certain recommendations are made as to duration of exclusion of patients and of "contacts" with them, these recommendations are subject to the proviso that *each case as it occurs requires and should receive individual consideration.*

Scarlet Fever

A. RULES FOR EXCLUSION OF INDIVIDUALS

(1) *As regards each child attacked by the disease*

39. (*a*) *When treated in the isolation hospital* he is usually detained for about six weeks, and longer if any mucous discharges continue. After return home, in view of the occasional protracted infectiousness of patients with such discharges, and sometimes even of those without them, a notice should be sent to the teacher, and a notice should also

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* In this connexion the provisions of Article 53 (*b*) of the Code for 1909 (quoted on p. 280) must not be overlooked, and it must be remembered that, if the Local Education Authority so direct, the S.M.O. will have full power to prolong the period for which any children have been excluded from school owing to sickness.

be given to the parent to the effect that the patient should not attend school for two weeks.*

(b) *When the patient has been treated at home* the same rules apply exactly, assuming that the patient and his rooms have been effectively disinfected after the illness has ended.

(2) *As regards children living in infected houses*

40. (a) *When the patient has been removed to the isolation hospital* the teacher and the parents should be instructed to keep all children living in the same house away from school for two complete weeks from the day on which disinfection, subsequent to the removal of the patient, has taken place; and the parents of all the children in the house, especially the parents of the patient, should be instructed to keep these children out of contact with other children for the same period.

This interval, although longer than the longest recognized incubation period for scarlet fever, is desirable in the case of children because of the occasional occurrence of anomalous or slight unrecognized attacks.

(b) *When the patient is treated at home* no other children from the same house should attend school while the patient is infectious, nor for two weeks after the end of his period of isolation.

B. Rules for Closure of School

41. If there is active co-operation between the school attendance officers and teachers and the **M.O.H.**, school closure should only exceptionally be needed for scarlet fever. In school this disease usually spreads slowly from child to child, and not in the explosive manner characteristic of measles. Hence diligent search for slight cases and supervision of "contacts" should in most instances render school closure needless.

Diphtheria

A. Advantage of Bacteriological Examination

42. The examination of the throats of "contacts," whenever practicable, by bacteriological means, is a most important aid to precautionary measures against the spread of diphtheria.

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* A longer period, e.g. four weeks, may not infrequently be necessary, not only in view of the health of the patient, but also if the occurrence of mucous discharges or other circumstances indicate that some measure of infectiousness may persist after cessation of home or hospital isolation.

If a positive result is obtained in the case of children showing no evidence of diphtheria, the presence of some measure of infection must be assumed, though it will not be advisable to insist on the removal of such patients to an isolation hospital.

It is recognized that in many sanitary districts arrangements do not exist for such examinations; but it has been thought better to set forth the line of action commonly adopted in the best-organized sanitary districts. Clinical examination of contacts and other children often throws valuable light on the origin of outbreaks of diphtheria. Particular attention should be paid to children who have been absent without known cause, or who show evidence of pallor, enlarged glands, or sore noses.

B. Rules for Exclusion of Individuals

(1) *As regards each child attacked by the disease*

43. (*a*) *When treated in the isolation hospital* the patient should, when practicable, be detained until three successive swabs taken on different days have given consistent negative results. These swabs should not be taken until at least forty-eight hours have elapsed since the last application of any disinfectant to the throat.

In view of the debility left by an attack of diphtheria, and the possible return of infectivity in the secretions of the nose or throat, a notice should be sent to the teacher stating that the child should not return to school for four weeks after return home.*

(*b*) *When the patient has been treated at home* three successive negative swabs should, when practicable, be obtained as above; and after disinfection of the patient and his rooms and belongings, the same period of subsequent abstention from school attendance as above should be enjoined.

(2) *As regards children living in infected houses*

44. (*a*) *When the patient has been removed to the isolation hospital* the teacher and the parent should be instructed to keep all children living in the same house away from school during the next two complete weeks, or even longer, unless these children have undergone bacteriological examination with negative result.

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* Sometimes this period may be reduced to two weeks.

This interval is desirable owing to the frequent occurrence of slight cases of diphtheria and "carrier" cases.

(*b*) *When the patient is treated at home* no other child from the same house should attend school while the patient is infectious, nor for four weeks afterwards.*

C. RULES FOR SCHOOL CLOSURE

45. Although diphtheria, like scarlet fever, and unlike measles, usually spreads comparatively slowly in schools, it is apt to be very persistent, and not infrequently causes serious mortality, especially among children under 5 years old. For these reasons, when cases of this disease occur in an infant school, there should be no hesitation in excluding children from attendance who are below the age of compulsory school attendance. This latter remark applies also for measles and whooping-cough.

Closure of other classes of the school should be resorted to only after clinical examination and, where practicable, bacteriological investigation for the detection of diphtheria bacilli in the pharyngeal or nasal mucus of children who have had slight sore throats, and of all other children who have been in contact with diphtheria patients, has been made.

The need of protracted exclusion from school of recent diphtheria patients has already been emphasized. The systematic use of these measures should obviate the need for school closure for diphtheria.

Other Notifiable Diseases

46. Children coming from houses in which have occurred cases of erysipelas or of enteric (typhoid) fever, who are not themselves ill, need not as a rule be excluded from school. Nor is school closure required for either of these diseases, except in the rare instances in which enteric fever is due to some condition directly connected with the school

Measles

A. CHARACTERISTICS OF THE DISEASE

47. Certain facts need to be borne in mind in adopting preventive measures against measles. In towns the attack-rate is highest in the third, fourth, and fifth years of life, while the death-rate caused by the disease is highest in the second year of life. After the age of 5 the death-rate caused by it is rela-

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*Sometimes this period may be reduced to two weeks.

tively very small. These facts clearly indicate the importance of postponing an attack of measles, and of adopting special measures to ensure increased safety for children under 5.

Persons seldom contract measles a second time, and, as in populous districts epidemics commonly recur every two or three years, most of the older children are protected against it by having passed through a previous attack. This rule may not apply to a country village, in which epidemics may be absent for a long series of years.

The early infectiousness of measles while the symptoms are only those of a common "cold" is another marked feature of this disease. It is not unlikely that a majority of the total cases are infected by patients in this early stage. The incubation period from infection to the commencement of catarrhal symptoms is twelve to fourteen days, with fair constancy.

Although measles is very infectious its infection does not appear to be long-lived, nor to be commonly conveyed by healthy persons. It thus differs from smallpox, scarlet fever, and diphtheria.

But though there is reasonable ground for the opinion that measles is not readily, if at all, conveyed to school by healthy children coming from infected households, it is desirable, particularly in view of the greater fatality of attacks of measles in children under 7 years of age, to assume the possibility of such spread by intermediaries in regard to scholars attending the infant school, and to act accordingly as stated below.

B. Rules for the Exclusion of Individuals

(1) *As regards children suffering from the disease*

48. Children attacked by measles should be kept from school for four weeks.

(2) *As regards other children living in infected houses*

49. In large towns, and in the smaller districts in which the majority of children over 7 years of age who are attending public elementary schools have had measles, the practice is frequently adopted, when measles breaks out in a household, of excluding from school attendance only those children of the same household who attend the infant school, and those older children of the same household who have not had measles. These particular children of the same household should be excluded from school until twenty-one days from the date of onset of the illness of the last patien with measles in the house.

50. The above procedure can be recommended as the

result of experience in large districts. It is a compromise which is obviously not a counsel of perfection, and may need future modification. Even under present conditions the procedure may need to be modified in accordance with the special circumstances of a particular district, with especial reference to its past history as to measles. The schedules for the medical inspection of school children, if kept carefully, will, in course of time, place at the disposal of the **M.O.H.** and of the **S.M.O.** the history of each child as to measles as well as to other infectious diseases, and they will thus be able to decide, when a case of measles occurs in a particular class, which scholars in that class should, and which should not, be excluded from attendance at school.

C. RULES FOR SCHOOL CLOSURE

51. School closure has probably more frequently taken place on account of epidemics of measles than for any other disease, but as the closure has been commonly deferred until a large proportion of the children were already absent, it has proved useless, in populous districts at least, for the purpose of preventing the spread of the disease.

If measles is introduced into a school, the first crop of secondary cases will occur about twelve days after the original case, and in twelve days more there will be a second crop comprising the majority of the unprotected children. Thus school closure, as ordinarily practised after the second crop of cases has occurred, fails to prevent an epidemic. In view of this experience a class closure of short duration after the occurrence of the first case of measles in the class may be substituted, the class being closed on the ninth day after the sickening of the first child, for a period of five days only. After this period, only those who have sickened need be excluded, along with those in the same households who have not had measles or who attend the infant school.

D. WARNINGS TO PARENTS

52. Warning notices to parents have been found to be valuable in preventing the spread of measles through the attendance at school of infecting children. These warnings should be sent out as soon as measles has appeared in a class, the parents being warned to watch their children and to keep them from school if the slightest symptoms of a "cold" develop during the following three weeks.

The warning notice should also suggest that the parent should at once inform the teacher if these symptoms develop.

The teacher can then report the case to the **M.O.H.** and the **S.M.O.**

Whooping-Cough

53. The rules as to exclusion from or closure of school for this disease should be similar to those for measles, except that the infection of whooping-cough probably lasts six weeks, and the children in the house who attend the infant school should therefore be excluded from school for this period, or as long as the cough continues.

Mumps and Chickenpox

54. Three weeks' isolation should be allowed for cases of mumps, and the same period, or until all scabs have disappeared, for cases of chickenpox. Inquiry should be made as to the vaccination of supposed cases of chickenpox.

In chickenpox it is well to exclude from attendance at the infant school all children of the same family as the patient. In mumps the same practice, owing to the long incubation period of this disease, involves much greater interference with school work; and, in view of this fact and of the absence of danger to life, the exclusion may be confined to the patient himself.

Pulmonary Tuberculosis

55. Pulmonary tuberculosis in a recognizable form is seldom a large factor in school life. Where it is known to exist, either through the medical inspection of children or apart from this, the affected scholar should be excluded from school in his own interest, and in that of the school, if the patient has cough with or without expectoration. (*See* p. 256, footnote.)

GENERAL NOTES AS TO PROCEDURE

56. In any case in which the **S.A.** require the closure of a public elementary school the notice should be addressed in writing to the correspondent of the managers, and should state the grounds on which the closure is deemed necessary. It should be signed either by an authorized officer of the **S.A.** in pursuance of their resolution, or by two members of the **S.A.** A copy of the notice should be sent to the **S.M.O.**

All such notices must specify a definite time during which the school is to remain closed; this should be as short a period as can be regarded as sufficing on public health grounds, since a second notice may be given before the expiration of the first, if it should be found necessary to postpone the reopening of a school.

57. Reports of **M.O.H.** to **S.A.**, advising the closure of a

school or schools in any district, are to be treated as "special" reports within the meaning of the General Order of the L.G.B. of March 23rd, 1891, and copies of them are required by Article 18 (15) and (16) of that Order to be sent to that Board and to the County Council. These reports should state the grounds upon which the M.O.H. advocates the closure of the school or schools in preference to the exclusion of particular scholars.

68. Any directions or authorizations given by the S.M.O. with respect to the question of excluding individual scholars on the ground that their exclusion is desirable to prevent the spread of disease must be embodied in a certificate signed by him; and a copy of every certificate must be furnished to the Local Education Authority (Article 53 (*b*) of the Code of 1908). The certificate must be produced if required to any Inspector or officer of the Board of Education's Medical Department.

It is understood in all cases that thorough disinfection is carried out. As a further safeguard it is desirable to insist upon a medical certificate of freedom from infection when a child returns to school after an infectious illness.

Typhus and enteric fever are not included in the list. They, of course, rarely require consideration. In either, three weeks may be adopted as the period of quarantine; and four weeks as the earliest date of return to school after an attack, if all symptoms have disappeared and convalescence is complete.

The duration of ringworm, ophthalmia, impetigo, and scabies is indefinite; and children suffering from any of these should, as a rule, be excluded or referred for treatment.

Inspection of schools.—The following schedule includes the principal points that require attention in the sanitary inspection of day schools:—

Name of school.—Character (elementary, secondary, technical). Local education authority.

1. *Position and surroundings of school.*—Nature of soil and subsoil; site, aspect, etc.
2. *Playground.* — Size; covering of paving; drainage; buildings or fixtures in; cleanliness.

3. *School buildings* [plans].—Structure, entrances, corridors, staircases, central hall, school-rooms, class-rooms. Number of storeys. Infant schools. Special departments for cookery, laundry work, handicraft, science, drawing, medical inspection, school meals. Open-air class-room accommodation.
   (*a*) Structure.—Condition of roofs, walls, floors, ceilings. Purpose of rooms.
   (*b*) Cubic capacities and accommodation: superficial area and cubic space per child. Overcrowding in class-rooms.
   (*c*) Heating.—Mode, radiation, convection; fire-places, stoves, hot pipes, or other methods; temperature in summer and winter.
   (*d*) Lighting. Mode; degree; windows, size and position; means of artificial lighting.
   (*e*) Ventilation.—Methods: natural or artificial; measurements of CO_2. Standard may be $\frac{10}{10,000}$. Air supply.
   (*f*) School furniture and fittings. Desks and seats. Gymnasium. Teaching appliances — blackboards, slates, pencils, sponges.
   (*g*) Cleanliness. — Arrangements for; scrapers. Dry cleaning. Periodical disinfection.
4. *General sanitation.* — Refuse removal; receptacles; ashpits, structure and condition of; sanitary conveniences (water or earth); separation of sexes; type and character; number; condition; arrangement; position; urinals, accommodation, flushing; drainage; surface and soil drains; rain-water; sink wastes; cesspits (cover, structure, cleansing); relation to well and land drainage; disconnection and ventilation; trapping, testing, etc.
5. *Lavatory, bath- and cloak-room accommodation.*—Position; structure; number of basins; water supply; towels; clothes-hooks; drying arrangements; size, heating, and ventilation of cloak-room. Baths.
6. *Water supply.*—What provision; if well, position and covering; surroundings of well; quantity and adequacy of supply. Playground tap. Water-filters. Storage and distribution.
7. *Master's house.*—Position, size, accommodation; general sanitation. Teachers' rooms and accommodation.

   General.—Number of teachers to scholars. Number on roll and average attendance. System of medical inspection in vogue. General result of records as to personal hygiene of children. Infectious diseases. Hours of school and playtime. Physical exercises. Attitude of children in school.

The medical inspection of school children. —School doctors were first appointed in Sweden in 1840 (in connexion with training colleges), and in 1883 at Frankfort. Systematic medical inspection was introduced at Wiesbaden in 1896, and the methods then adopted became general in the large towns of Germany. Practical interest had been taken in the question in England from 1880 onwards. In 1890 a medical officer was appointed by the London School Board, and in 1907 Parliament instituted a national School Medical Service, which proved in fact to be the first national system of school doctors.

The section of the Education (Administrative Provisions) Act, 1907, which concerns medical inspection of school children (section 13) is as follows:—

13. (1) The powers and duties of a Local Education Authority under Part III. of the Education Act, 1902, shall include—

[(*a*) Power to provide for children attending public elementary schools, vacation schools, vacation classes, play centres, etc.]

(*b*) The duty to provide for the medical inspection of children immediately before or at the time of or as soon as possible after their admission to a public elementary school, and on such other occasions as the Board of Education direct, and the power to make such arrangements as may be sanctioned by the Board of Education for attending to the health and physical condition of the children educated in public elementary schools: Provided that in any exercise of powers under this section the Local Education Authority may encourage and assist the establishment or continuance of voluntary agencies, and associate with itself representatives of voluntary associations for the purpose.

The Board of Education require at least three medical inspections of each child during school life. The purpose of the School Medical Service is—(*a*) to select by systematic medical inspection the ailing child, and to make available effective means for treatment; (*b*) to provide healthy school conditions; and (*c*) to establish physical education and a sound physique in childhood. The Code of Regulations for Public Elementary Schools sets out clearly the requirements in respect to school hygiene and medical inspection now imposed upon all the 319 Local Education Authorities which are responsible for the State system of education throughout England and Wales, and it will be convenient to quote these requirements fully :—

The Teaching of Hygiene and Physical Training

2. In schools for older scholars the subjects described below should be taught in a manner suitable to the age and capacity of the several classes. It is not necessary that all the subjects should be taught in every class, and the curriculum as a whole may be modified when the Board are satisfied that the needs of the scholars or the circumstances of the school require it. . . . .

(9) *Hygiene and physical training*, including exercises in proper breathing; instruction adapted to the ages and sexes of the scholars in the elementary rules of personal health, particularly in respect of food, drink (including alcohol*), clothing, cleanliness, and fresh air; and careful cultivation of a correct posture at writing and other lessons. In any course of physical exercises the general physical development of the scholars should be aimed at, and the official syllabus of physical training should be followed. The scholars of any school not situated wholly on a ground floor should be practised in fire-drill. Instruction and practice in swimming may also be included in the time-table.

Sanitation of School Premises

18. The premises of the school must be healthy, safe in case of fire, must have suitable and sufficient sanitary and cloak-room accommodation for the scholars in attendance and for teachers, must be adequately lighted, warmed, ventilated, cleaned, and drained, must be kept in proper repair, and must be sufficient, convenient, and suitably arranged for the instruction of the children in attendance according to their age.

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* Lessons in "Temperance," where given, should be in conformity with the Official Syllabus dated 1st June, 1909.

Provision for Medical Inspection

25.—(*c*) Every school or department must comply with such conditions, regulations, and requirements imposed by the Education Acts as are applicable to the type of school in question. Satisfactory provision must be made for the medical inspection of children attending the school in accordance with section 13 (1) (*b*) of the Education (Administrative Provisions) Act, 1907.

58.—(*a*) Arrangements must be made, so far as practicable, for carrying out the work of medical inspection in the school premises, and the managers shall give such reasonable facilities as are required by the Local Education Authority for the purpose.

(*b*) The Board must be satisfied that provision has been made for the medical inspection of all children admitted to the school in the year, and of all children who are expected to leave school in the year—the year in each case being the twelve months ending on the 31st of July.

Attendance at Open-Air Schools, etc.

44. In making up the minimum time required in order that an attendance may be reckoned for grant there may be included—

(*g*) Any time spent during the ordinary school-term under arrangements and according to a time-table approved by the Board at an open-air school, school camp, or other place selected with a view to an improvement of the health and physical condition of the children.

(*h*) (i.) Any period occupied by the medical inspection or treatment of scholars, conducted by or under the authority of the Local Education Authority in pursuance of the requirements of section 13 of the Education (Administrative Provisions) Act, 1907, whether such inspection is conducted in the school premises or (in special circumstances) in some other place appointed for the purpose of the Local Education Authority with the approval of the Board.

The Board may at any time require the Local Education Authority to furnish them with a special report by the S.M.O. on the working and effect of any arrangements made under this Article.

The School Medical Officer

For the purposes of this Code "School Medical Officer," it may here be repeated, means a medical officer named by the Local Education Authority, and recognised as such by the

Board. In exceptional cases the Board will recognize separate S.M.O.s for separate parts of one area.

Closure of School and Exclusion of Children

45. The school, department, or infants' division must have met not less than 400 times in the school year.

(*b*) If the requisite number of meetings has not been held owing to a closure of the school under Article 57, or under the advice or with the approval of the **S.M.O.**, or for any other unavoidable cause, the grant may be paid in full, provided that the requirements of this Article are satisfied after an allowance of nine meetings has been made for each week of such closure.

53.—(*a*) No child may be refused admission to a Public Elementary School on other than reasonable grounds.

(*b*) Where the Board are satisfied (i.) that proper arrangements have been made by the Local Education Authority for enabling the **S.M.O.** to ascertain and certify cases in which the exclusion of children from school is desirable, and (ii.) that the **S.M.O.** has authorized the exclusion of certain children from the school—

(1) on the ground that their exclusion is desirable to prevent the spread of disease, or

(2) on the ground that their uncleanly or verminous condition is detrimental to the other scholars, or

(3) on the ground that, owing to their state of health or their physical or mental defects, they are incapable of receiving proper benefit from the instruction in the school,

the exclusion of such children shall be deemed for the purposes of this Code to be exclusion on reasonable grounds.

For the purposes of this provision the Local Education Authority may direct that no children who have been excluded under the authority of the **S.M.O.** or under Article 57, or who have been absent from school owing to sickness, shall be re-admitted to school if the **S.M.O.** is not satisfied that they can attend school without risk to themselves or others.

Every direction or authority given by the **S.M.O.** must be embodied in a certificate signed by him. A copy of every certificate must be furnished to the Local Education Authority and must be produced, if required, to any Inspector or officer of the Board's Medical Department.

57. If the **S.A.** of the district in which the school is situated, or any two members thereof, acting on the advice of

the **M.O.H.**, require either the closure of the school or any department thereof or the exclusion of certain children for a specified time, with a view to preventing the spread of disease or any danger to health likely to arise from the condition of the school, such requirement must at once be complied with.

The **School Medical Service** has been organized as a part of the Public Health Service and not upon an *ad hoc* basis. In many areas there are under the **S.M.O.** Assistant Medical Officers, school nurses, attendance officers, and various types of voluntary workers who assist. There are upwards of 1,200 Medical Officers engaged in the School Medical Service, of whom more than 100 are women. The statutory medical inspection, which is usually carried out on the school premises, takes account of the following points in each child:—

(*a*) Name, age, address, school, date of inspection, standard, clothing and foot-gear.

(*b*) Personal history, previous illnesses (measles, whooping-cough, chickenpox, scarlet fever, diphtheria, and other illnesses), and family medical history.

(*c*) General conditions—height, weight, nutrition, cleanliness.

(*d*) Special conditions—teeth, nose and throat (tonsils, adenoids, glands), eye disease, vision, ear disease, hearing, speech, mental condition.

(*e*) Disease and deformity—including condition of heart and circulation, lungs, nervous system, tuberculosis,* rickets, deformities, spinal disease, infectious or contagious disease, and any other disease and defect present.

As a result of medical inspection it has been found

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* The Public Health (Tuberculosis) Regulations, 1912, Art. 6, require the **S.M.O.** to send weekly lists of all cases of tuberculosis to the **M.O.H.** of the district within which the places of residence of the children are situate.

(1916) that of the six million children in the elementary schools of England and Wales about 10 per cent. suffer from serious defects in vision, hearing, or nutrition, 20–40 per cent. from extensive decay of the teeth, and 1–3 per cent. from obstructive adenoids; about 1 per cent. have ringworm; 3 per cent. have suppurating ears, 1 per cent. have recognizable tuberculosis, 2 per cent. have heart disease, and 10 per cent. have unclean heads.

The procedure in regard to these defects is as follows: The Local Education Authority are responsible for the medical inspection through the **S.M.O.**, who reports to the Authority his findings in respect of individual children; they communicate the findings to the children's parents, whose duty it is to obtain the necessary treatment. In order to ensure that defective children receive the treatment they require, it is necessary to "follow up" the case and in due course to re-examine. In this proceeding the parents, teacher, school nurse, attendance officer, and school doctor all take a share. The work is frequently organized under Care Committees, who also make themselves responsible for the management of school feeding, after-care work, employment of children, etc.

Medical treatment of school children.—Local Education Authorities have power to treat defects found on inspection or provide ameliorative or preventive methods as follows: (1) By *improvement of school arrangements,* including the sanitation of premises, curriculum, physical exercises, open-air classes and schools, and school hygiene generally. (2) By *exercise of powers under special Acts relating to school children,* particularly such legislation as the Elementary Education (Blind and Deaf Children) Act, 1893, the Elementary Education (Defective and Epileptic Children) Acts, 1899 and 1914, the Education (Provision of Meals) Act, 1906, the Children Act, 1908, and the Mental Deficiency Act, 1913. (3) By *co-operation with the* **S.A.** in regard to the prevention of the spread of infectious diseases, disinfection, sanitation of school premises, and various questions of domestic and home hygiene. (4) By *reference to a medical practitioner.* (5) By *the school nurse.* (6) By *the provision of suitable spectacles* at reduced rates, or in necessitous cases free of charge. (7) By *making contributions to hospitals, dispensaries, and nursing and children's care associations.* The Board have made it permissible for Authorities to include among the conditions of contribution to this kind of institution a provision allocating reasonable remuneration to the medical staff responsible for carrying out the treatment provided. (8) Lastly, by *the establishment of school clinics* managed by Local Education Authorities—both general clinics and dental clinics (480 now established).

The Local Education Authorities (Medical Treatment) Act, 1909, requires that where a provision is made by the Authority for medical treatment there shall be charged to the parents some amount not exceeding cost. Payment may be remitted if the Authority are satisfied that the family is necessitous. Under Regulations issued by the Board of Education, grants-in-aid are now made for medical inspection and treatment.

Open-air schools.—The four principal means of physical education are the teaching of hygiene and cleanliness, the feeding of school children, systematic physical training, and open-air schools. Such open-air education takes the following forms: (1) Classes held in playgrounds, gardens, or parks; (2) school journeys and country schools; (3) open-air class-rooms; (4) open-air day schools; (5) residential open-air schools, and (6) children's sanatoria. Such methods are particularly valuable for anæmic, debilitated, malnourished, or weakly children. The advantages are fresh air and sunlight (heliotherapy), improved dietary, rest, hygiene, medical care, and special educational methods. The criteria of the effect of these methods are height and weight, chest expansion, muscular tests, blood tests, mental tests, improved health, and school attendance. Typical day open-air schools exist at Bradford, Sheffield, Birmingham residential schools at Clacton and Rochdale; sanatoria at Leasowe and Alton.

Special schools for defective children.—Direct and indirect treatment has been provided for blind, deaf, mentally and physically defective, and epileptic children found in the elementary schools. Physical defects in children include all forms of crippling and disablement; mental defects include idiocy, imbecility, feeble-mindedness, moral deficiency, backwardness, cretinism, etc. Education or guardianship is required for all these types.

The Elementary Education (Blind and Deaf Children) Act, 1893, places upon the parent and School Authority the responsibility of education of a child who is blind or deaf. The Authority must obtain suitable education for such child in a school certified by the Board of Education, either established by the Authority or receiving contributions from such Authority with or without representation. Two or more Authorities may combine for this purpose. The period of compulsory education must extend to 16 years.

The Elementary Education (Defective and Epileptic Children) Act, 1899, is adoptive only, and gives power to a School Authority to determine what children in its district are defective and epileptic. "Defective" children are those who "by reason of mental or physical defect are incapable of receiving proper benefit from instruction in the ordinary public elementary schools," and the defect must be certified by a medical practitioner approved by the Board of

Education. Under the Elementary Education (Defective and Epileptic Children) Act, 1914, Authorities must make provision for the education of mentally defective children by providing or contributing to special classes or schools for the purpose, with or without "boarding-out" accommodation, and periodically shall examine medically such children to ascertain whether they are fit for ordinary school. (*See also* Mental Deficiency Act, 1913, p. 654.) The parent may, after consultation, be compelled to send his defective child to such special school, which shall be entitled to grants-in-aid and the receipt of payments from parents or Poor Law. Compulsory education extends under this Act also to 16 years.

Under these Acts 48 schools exist (1916) for the blind, 49 for the deaf, 180 for the feeble-minded, 61 for the physically defective, and 6 for epileptics. Some of these are residential schools of the nature of "colonies." There are 20 open-air schools and 29 schools for tuberculous children. Not less than 30,000 children are educated in these "special" schools, which are controlled by regulations under the Board of Education and receive additional grants-in-aid. Appropriate methods of education, including manual work, are adopted, and medical examination takes place annually. Special classes exist also for retarded and myopic children.

The London County Council (General Powers) Act, 1907 (sections 36 and 38), provides for examination and cleansing of verminous school children, and the General Powers Act of 1908 (section 6) empowers **S.A.s** in London to appoint health visitors for the proper nurture, care, and management of young children and the promotion of cleanliness. Under this Act the **L.G.B.** have issued the Health Visitors (London) Order of 1909, making regulations for such appointments. The Public Health Acts Amendment Act, 1907, requires for the **S.A.** lists of school children suffering from infectious disease and their exclusion from school. The Education (Provision of Meals) Acts, 1906 and 1914, provide for feeding school children under certain conditions, with or without payment by parents. Half of the approved expenditure on school meals is now paid by the Exchequer. The Employment of Children Act, 1903, the Labour Exchanges Act, 1909, and the Education (Choice of Employment) Act, 1910, contain provisions regarding the employment of children which call for the attention of the school doctor. The Children Act, 1908 (sections 12 and 122), deals with neglected and verminous children (*see* p. 649).*

Teaching of hygiene and physical training.—Article 2 (9) of the Code of Regulations for Elementary Schools governs the teaching of these subjects, and under it three special syllabuses have been drawn up by the Board of Education for lessons in hygiene, temperance, and physical exercise. The Syllabus of "Temperance" Teaching is designed for actual use in the school, but the Lessons in Hygiene and Physical Training have relation, in the first instance, to the necessities of students in training for teachers (collegiate and non-collegiate). The Syllabus of Physical Exercises (1909) is based upon the Swedish system, and contains a series of model tables of exercises, dancing steps, and organized games suitable for elementary and secondary schools. The Board have also issued instructions for the teaching of infant care and management to elder girls, in conjunction with housewifery or independently.

School Medical Officer's annual report.—The Board of Education require an annual report on the whole subject of School Hygiene, under the following heads:—

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* **Children under the poor law, etc.**—There are some 70,000 children in poor law institutions (workhouses, sick asylums, certified schools, district schools, etc.), and 184,000 more children receive relief in one form or another. (For particulars concerning these schools see *Children under the Poor Law*, L.G.B. Circular, 1910.) Further, there are some 100 reformatory and industrial schools, accommodating 18,000 children, committed under the Home Office, for whom medical care, physical training, etc., must be provided.—*Report of Departmental Committee on Reformatory and Industrial Schools*, 1913.

(*a*) General review of the hygienic conditions prevalent in the schools in the area of the Local Education Authority in respect of such matters as surroundings, ventilation, lighting, warming, equipment, and sanitation, including observations on the type and condition of sanitary conveniences and lavatories, water supply for washing and drinking purposes, the cleanliness of schoolrooms and cloakrooms, arrangements for drying children's cloaks and boots, and the relation of the general arrangements of the school to the health of the children.

(*b*) General description of the arrangements which have been made for the co-relation of the School Medical Service with the Public Health Service and for the organization and supervision of medical inspection, and an account of the methods of inspection adopted.

(*c*) Statement of the extent and scope of the medical inspection carried out during the year.

(*d*) General review of the facts disclosed by medical inspection, under the headings contained in the schedule.

(*e*) Review of the relation of home circumstances and social and industrial conditions to the health and physical condition of the children inspected, so far as facts bearing on this point have come under notice.

(*f*) The methods employed or available for the treatment of defects.

(*g*) Action taken to detect and prevent the spread of infectious diseases.

(*h*) The methods adopted, and the adequacy of such methods, for dealing with blind, deaf, mentally or physically defective, and epileptic children under the Acts of 1893 and 1899.

(*i*) The methods and results of instruction in personal hygiene and temperance in the public elementary schools in the area; the methods and results of physical or breathing exercises in the schools; arrangements for open-air schools, school camps, etc., under Article 44 (*g*) of the Code of 1908.

(*j*) Account of miscellaneous work, such as the examination of scholarship candidates, pupil-teachers, or teachers of any grade.

Children under 5 years of age.—Although children under 5 years of age do not come within the school system of compulsory education, attention to their health is an important part of Preventive Medicine in relation to the school child. The conditions which lead to high infant mortality (p. 742) increase the death-rate up to 5 years, and affect older children. Preventive methods must therefore begin before and during infancy (prenatal, natal, postnatal), and include (*a*) *maternity centres*, *schools for mothers*, *infant-welfare centres* for the care of the mother and infant (weighing and examination of infant, instruction in mothercraft, home visitation); (*b*) *crèches* or day-nurseries for supervision of the child in the mother's absence; (*c*) *nursery schools* for children aged 2-5 for training in habits, hygiene, etc.; (*d*) *infant schools* for elementary education; and (*e*) *baby-clinics* and *infant hospitals* for medical and surgical supervision and treatment.

CHAPTER VIII

HOSPITALS

General considerations.—All that has been said in respect of site, surroundings, and construction of houses applies with still greater force to hospitals. Pure air and light are of especial importance in sick-wards, which are occupied day and night The site should be as dry and open as possible, preferably on a porous subsoil, not exposed to smoke or effluvium borne by wind, and not unduly sheltered by trees, buildings, or hills. If practicable the site should be open to the south and west, and convenient of access.

Wards.—Long wards should face east and west so as to admit sun on each side alternately, and if any deviation is necessary it should preferably be such as to give a south-east and north-west aspect (*Thorne Thorne*). Single-storey hospitals are preferable, as affording the freest circulation of air. Each ward is then completely detached from the rest, and the absence of stairs is advantageous; but from motives of economy and convenience of concentration two or more storeys are usually built.

Small wards are inevitable in cottage hospitals, and, indeed, in all hospitals, since provision has to be made for the isolation of severe or infectious cases, and for the classification of patients according to sex, and sometimes according to disease. As a general proposition, however, large wards are more readily ventilated, warmed, and lighted, more economical in construction and management, and more convenient as regards nursing.

For long wards the width should be 24 to 30 ft., the height 13 to 14 ft., and the length such as to allow a cubic space per patient of at least 1,200 ft. Not less than 2,000 ft. is considered necessary in an infectious-diseases or lying-in hospital, or for severe surgical cases. It is not permissible to obtain this space by increasing the height. As already explained, extreme height is of little utility as regards ventilation, and in hospitals it is essential to have plenty of floor space around each bed. For nursing purposes at least 90 sq. ft. per bed is necessary, and more will be required if the ward is largely used for clinical teaching. Wherever there is any possibility of septic or other infection—as, for example, in surgical wards, lying in wards, and wards for infectious diseases—wide separation of beds is important. In such cases 12 ft. of wall and 130 to 140 ft. of floor space should be allowed. It is found that for convenience in nursing the number of beds in one ward should not exceed 32, and usually 24 or 28 would be preferable.

The beds are arranged with their heads to the wall, facing into the ward. Each bed should be placed between two adjoining windows, the space between the windows being not less than a foot wider than the bed. At most two beds may be allowed in one space, the interval between them being at least 3 ft. The intervals between the windows of a ward should be such as to allow of this arrangement. The windows should reach to within a foot of the ceiling.

All the surfaces should be impervious, smooth, and washable, and all ledges, crevices, and stagnant corners in which dust may lodge must be avoided. The floors may be paraffined or waxed, the walls lined with tiles or glazed brick or Parian cement, or, in the absence of such materials, simply painted.

Heating and ventilation.—The heating may be effected by open fire-places or ventilating stoves, or both, and it is well to have in addition coils of steam or hot-water pipes with radiators in corridors. Ventilation must be provided for to the extent of at least 3,000 ft. per head per hour, and it may be taken as a safe rule that the whole air of the ward ought to be changed thrice hourly, so that the hourly supply of fresh air should be three times the cubic capacity of the ward. Ventilation may be by windows on opposite sides of the ward; the windows should be double-hung sashes with fanlight above, falling inwards, hopper fashion, with side cheeks to prevent down-draught. One square foot of window to every 70 cub. ft. of ward space is a suitable proportion.

Extraction may be provided for by fire-places, stoves, windows opening at the top, Sheringham valves near the ceiling (p. 201), chimney shafts, warm outlet flues, and in other ways. Special extraction shafts, with inlets at or near the ceiling, are desirable. Such shafts may be carried up alongside or surrounding the chimney or stove flue, so as to utilize the waste heat as a motive power; or, independently of these, with a gas jet in the inlet to create an upward current. Some hospitals for infectious diseases have an extraction shaft upon a larger scale, the foul germ-laden air being made to pass through a gas furnace. Most, if not all, of the germs are no doubt destroyed in this way, and the rest are prevented from diffusing horizontally. This precaution was suggested by the Hospitals Commission, and is especially important in regard to smallpox hospitals, which have been shown to be capable, under certain conditions, of acting as foci from which infection spreads through the air.

In many hospitals the heating and ventilation systems are combined. In any case it is desirable to make arrangements for warming the air passing into the wards. This may be done by means of ventilating fire-grates, ventilating stoves, or coils of hot pipes at the inlets. Windows, Sheringhams, and Tobins may suffice in warm weather. It is a common practice to place the inlets under beds, with the intention of avoiding draughts and supplying the purest air close to the patients.

In the most approved plans a cross-ventilated corridor or anteroom leads from one corner of the ward to the water-closets and slop sinks, and the bathroom and lavatory are similarly placed at the adjoining corner. At the opposite end is a nurse's room with a window overlooking the ward.

Hospitals for infectious diseases.—Reference has already been made to the need for greater cubic space and ventilation in such hospitals, and to the importance of guarding against the tendency to aerial spread of infection in certain diseases. The communication with the outside has also to be kept under strict control. It is desirable that "isolation hospitals" should themselves be isolated from other buildings, and even from thoroughfares, by reserving as wide an open space as possible. The boundary walls should be 6½ ft. high. Each disease must be isolated separately, and if possible in separate blocks, not less than 40 ft. apart, and the same distance from the boundary.* There should be no communication whatever between the different blocks, and the intercourse with the common administrative department should be as little as possible. As regards structure and arrangement of wards, the standards named in respect of general hospitals apply, except that not less than 2,000–2,500 cub. ft. are required per bed, and 130–180 ft. of floor space. A special block containing at least two or three small wards is necessary for doubtful cases, or cases not received into the principal wards. The site should be high and airy, on dry gravelly soil, removed from buildings but not too exposed. It should not in any case be less than 2 acres in extent, and the number of patients per acre should not exceed 10–20.

The essential parts of a hospital for infectious diseases are—

1. An *administrative block*, including accommodation for the medical officers, matron, nurses, and servants; dispensary, kitchen, scullery, larder, and pantry; laundry, linen-room, store-room, coal-cellar, bathrooms, closets, etc. etc.

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* The L.G.B. require (1902) that a smallpox hospital should not be so placed as to have within a quarter of a mile a hospital (whether for infectious diseases or not), a workhouse, or any similar establishment, or a population of 200 persons; or within half a mile a population of 600 persons, whether in one or more institutions or in dwelling-houses; even where the above conditions are fulfilled, a hospital must not be used at one and the same time for the reception of cases of smallpox and of any other kind of disease.

2. *Hospital blocks*, namely, at least one for each disease to be isolated, and in each block at least two principal wards, one for each sex. Additional small wards for one or two beds are desirable. An "isolation block," consisting entirely of small wards, is most useful. Besides the wards, closets, sinks, and bathrooms, each block should contain a nurse's room, overlooking the ward, and so arranged as to serve as a scullery and ward-kitchen for minor cookery; linen-room, store-room, and coal-place. The nurse's sleeping-room must be away from the wards; it may be in the same block, but is more usually placed in the administrative block. Arrangements must be made for the patients from each block to take exercise in the grounds without coming into contact with each other. Small-pox hospitals should be entirely independent of those for other diseases. The drains of each block of wards should be trapped from the common drain, and ventilated separately by an inlet just above the trap and by ventilating shafts at their highest points.

3. *Auxiliary premises.*—Mortuary and post-mortem room; disinfecting room; stable and ambulance shed; porter's lodge, etc. The drainage, the water supply, and arrangements for heating need no special mention.

Typical systems of isolation. — Isolation hospitals are now most commonly built of the *pavilion* type and of one storey only, having *large or small wards.* The former are separated from each other by the entrance vestibule and nurse's duty room. (Fig. 25.) This arrangement allows of complete separation, cross-ventilation, abundant light, ready administration, and easy classification of patients. In the *small ward* or "block" type the wards are similarly separated, hold only two beds, and are each entered from the veranda (Fig. 26) or from a common corridor. The third type consists of *cells* or chambers in which

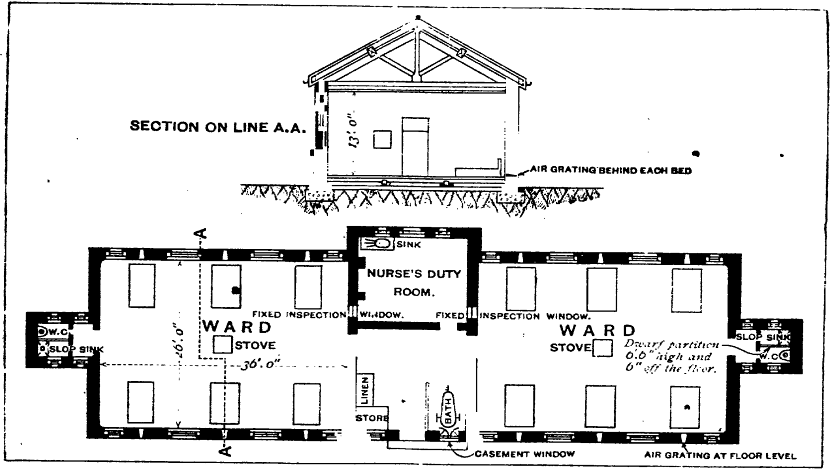

Fig. 25.—Isolation Hospitals. Plan of a Ward Pavilion for Twelve Beds. (L.G.B. Model.)

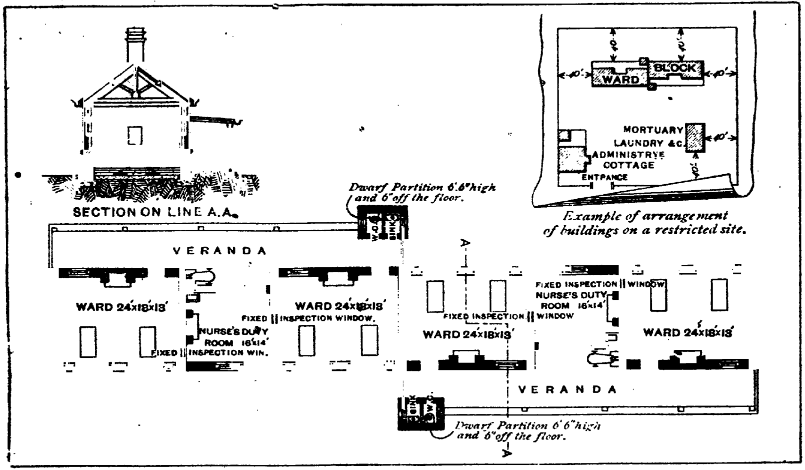
SECTION ON LINE A.A.
Dwarf Partition 6'.6" high and 6" off the floor.
W.C.
SINK
VERANDA
WARD 24'x18'x13'
FIXED || INSPECTION WINDOW.
NURSE'S DUTY ROOM 16'x14'
FIXED || INSPECTION WIN.
A
FIXED INSPECTION || WINDOW
NURSE'S DUTY ROOM 16'x14'
FIXED INSPECTION || WINDOW
WARD 24'x18'x13'
WARD 24'x18'x13'
VERANDA
W.C.
SINK
Dwarf Partition 6'6" high and 6" off the floor.
A
40'
WARD
BLOCK
MORTUARY
LAUNDRY &c.
ADMINISTRYE
COTTAGE
ENTPANCE
Example of arrangement of buildings on a restricted site.

Fig. 26.—Isolation Hospitals. Plan of an "Isolation" Block for Eight Beds. (L.G.B. Model.)

each patient is completely isolated from his neighbour by glass partitions (Fig. 27). Fourthly, there is the *cubicle* system, in which the dividing partition is only 7 ft. high. These types have been added to by the introduction of the *barrier* system, by which the patient is isolated by a simple cordon, implying exact and skilled isolation methods of nursing. Lastly, at Fazakerley, Liverpool, Rundle has introduced *bed isolation* only, an application of the barrier method without the barriers. Examples of these types may well form a part of any large hospital, but wise reliance upon any of them is dependent on two factors: first, the degree of infectiousness (enteric having short striking distance and smallpox long), and the skill and experience in aseptic methods of the nursing staff.

Number of beds.—The number of beds which should be provided has been stated as *one for each thousand of population*, but such an estimate can only be of the roughest kind. Much depends upon the character of the population, upon the number of diseases which it is proposed to isolate, upon the thoroughness or the reverse with which the policy of isolation is to be carried out, and lastly upon the question whether the hospital is intended to be a final and inelastic establishment, or merely a permanent provision sufficient for non-epidemic times but capable of rapid extension at a few days' notice in the event of serious epidemic. It is obvious also that averages are of little use as indicating the maximum possible demand for hospital accommodation at any given date, and it is not to be assumed that only one disease will be epidemic at one time.

By general consent, smallpox, scarlet fever, diphtheria, enteric fever, plague, and typhus are diseases which, for the public safety, ought to be

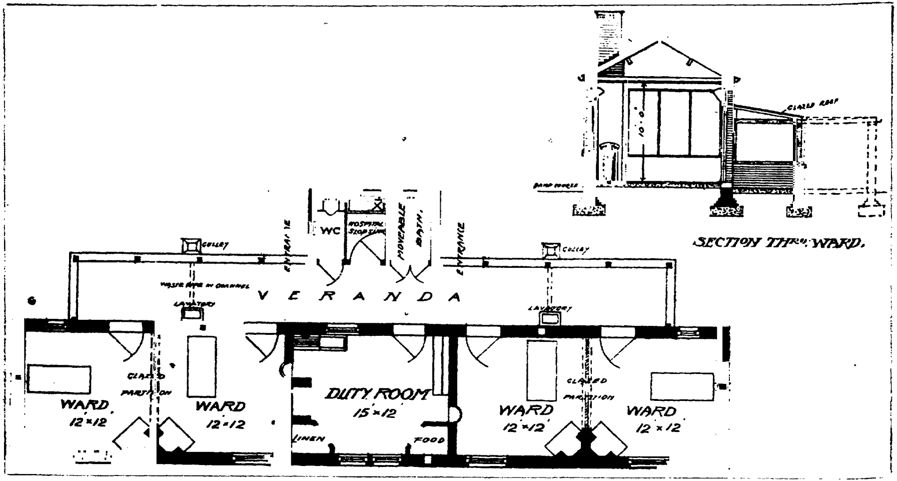

Fig. 27.—Isolation Hospitals. Plan of an Observation Block for Single Cases of Infectious Diseases, for Cases of Mixed Infection, or for Cases of Doubtful Diagnosis. (L.G.B. Model.)

treated in hospital whenever possible. Experience has shown that with compulsory notification and *free hospitals* it is possible to get into hospital practically all the smallpox, a great majority of the scarlet fever, diphtheria, and enteric cases, and all the plague and typhus cases, without recourse to compulsion.

To sum up, therefore, the provision of one bed per thousand population is not likely to be found excessive. Indeed, it will not suffice in the event of epidemics, and if such diseases as measles and whooping-cough are to be isolated, large additions will be necessary. It is, therefore, advisable to reserve a liberal area for future extensions, temporary or otherwise, and to construct the administrative portions upon such a scale as to suffice in case of such extension of the isolation blocks.

It is of the utmost importance, if isolation is attempted upon the large scale, to make the hospitals free, and this is only reasonable, since the public gain at least as much as the patient by his seclusion. The **S.A.** must not regard removal to hospital merely as a privilege sought by the patient and his friends, but as a concession on their part to the public safety. Any charges, however small and readily remitted, are deterrent in the very cases in which isolation is most needed. The revenue from patients' fees is at best a small fraction of the cost of maintenance, and the wholesale remission of them —without which the isolation of cases among the working classes is impracticable—has an appearance of charity which is naturally resented. An exception may be made in respect of the wealthy who are willing to pay suitable fees for the use of private wards and special nurses.

Cost.—The expenses to be incurred in respect of isolation hospitals are classified under the Isolation

Hospitals Act as (*a*) structural, (*b*) establishment, and (*c*) patients' expenses.

The great cost of permanent hospitals—rarely less than £200 and sometimes £400 per bed—has led to the substitution in many cases of temporary structures (£20–£50 per bed), more especially in the presence of an epidemic, when rapidity of construction is the first consideration. These may be tents, or buildings of wood and galvanized or corrugated iron. Wooden hospitals are common, and can be run up in two or three weeks. The walls must be made double, and it has been found advisable to fill up the hollow with sawdust. The floors must be raised above the surface of the ground. The roof may be slated or tar-felted. The foundation required is generally a four-course brickwork with air-bricks and damp-proof course. The dimensions and arrangements may conform to those of permanent buildings. The same may be said of galvanized iron huts, which are often used for hospital purposes. Tents can be erected still more rapidly, upon a wooden floor raised above the level of the ground. The canvas should be double. Recently other forms of temporary hospitals have come into use, including those of Doecker and Ducker types, both of which are convenient in use, and can be erected at a few hours' notice. They consist of a stout waterproof material stretched upon wooden frames, so shaped and numbered that they can be speedily put together to form a complete and weather-proof hut, ready for the reception of patients. Willesden waterproof paper is also used for the construction of huts. Sometimes a composite construction has been preferred, with an administrative block of stone or brick, and pavilion wards of corrugated iron and wood, costing about £120 a bed. It should be added that the L.G.B. does not, as a rule, sanction loans for the construction of temporary hospitals.

Temporary hospitals.—Their comparative cheapness and the rapidity with which they can be erected are important points in favour of temporary hospitals, but their proper function is to supplement, and not supersede, permanent buildings of brick or stone. They are less attractive in appearance than the latter, less comfortable, and more difficult to ventilate efficiently, and to keep warm or cool. True disinfection, such as to fit them for the reception of cases of different diseases, if not impossible, is at least less easy and less certain than in buildings with hard non-absorbent surfaces, free from pores and crevices. Their durability is far less than that of a permanent building, and an annually increasing outlay is needed in order to keep them in habitable repair. It is often claimed on behalf of temporary hospitals that no disinfection is necessary, since they can be burnt at the end of the epidemic, and renewed; but this plan, which would very soon prove more costly than the erection of permanent hospitals, has rarely, if ever, been put into practice. The economy in first cost is great, but is usually exaggerated. It must be remembered that the cost of erecting a permanent hospital, as ordinarily stated, includes the preparation and laying out of the site, fencing, drainage, water and gas supply, erection of accessory buildings, such as mortuary, disinfector, lodge, etc., and the whole cost of the administrative block. These are not usually included in the stated cost of "temporary" hospitals, although just as essential in the one case as the other. Furthermore, the cost *per bed* largely depends on the number of beds that are allowed in a given cubic space, and it will be found that, if the standard adopted in permanent hospitals is applied to all, the nominal accommodation in temporary hospitals will often be reduced by one-half or more. If the comparison is made upon equal terms, the saving in first cost is insufficient to compensate for the want of durability, and for every purpose of use permanent hospitals have great advantages. The liability to fire must not be forgotten. The only real advantage of temporary hospitals is, therefore, the *rapidity of erection*, and (except as a supplementary provision) this can only be important when the S.A. has failed in its obvious duty of providing a hospital without waiting for an epidemic. It is then frequently too late, however speedily the hospital is got ready. Means of isolation are needed at all times, in every large community, and it is even more important to endeavour to delay and prevent outbreaks by secluding a few "sporadic" cases than to grapple with epidemics already in existence.

In addition to the structural expenses there are the establishment costs, which include all expenses of maintenance, repairs, salaries, etc., working out often at about £20 to £30 per bed per annum. Then there remain the expenses of removing, feeding and providing for the patients, including medicine, appliances, disinfection, etc. Many hospitals would average say £10 or £12 per patient per annum. (For details see L.G.B. Report on Isolation Hospitals, by Franklin Parsons, 1912).

Effect of hospital isolation.—The justification for isolation is based on the broad ground that certain diseases are infectious; that is, are readily transmissible from the sick to the healthy. Infected persons act therefore as foci of the disease, and where such persons are left in the midst of densely populated communities there is a greater tendency for the disease to spread than if such persons are isolated away from others. Although it may be possible to isolate almost any case of infectious disease in a large house, where all the requisite precautions can be rigidly maintained during the whole period of infectiousness, it may be stated broadly that "home isolation" in smaller houses cannot be carried out effectively.

Hospital isolation has the further advantages of providing more skilled medical and nursing treatment, and removing the source of infection from house, clothes, materials, milk, etc. Where satisfactory isolation can be provided at home, hospital isolation may be unnecessary, and if a hospital is badly administered, or there is overcrowding, such home isolation may even be preferable.

It has been contended that hospital isolation has failed materially to reduce the prevalence and fatality of scarlet fever, and has led to "return cases" of that disease; that is, secondary cases of the disease occurring in the same household after the return home of the primary patient from hospital. These have been found to be about 1–3 per cent. of the number discharged. Simpson has shown that 80 per cent. of such return cases are due to discharges from mucous membranes. Local and antiseptic treatment and transference to less infective wards before leaving are likely to be more effective in preventing return cases than long detention.

Sanatoria for tuberculous patients.—The general principles of construction of institutions for the treatment of pulmonary tuberculosis follow those of hospital provision. But certain points require particular attention.

Site.—The area of land required for the site will depend upon the number of patients and the type of cases. The site of a sanatorium should be sufficiently large to permit of open-air employment of a considerable number of patients. It is desirable that a site of 50 acres should be provided for 100 patients, but an area of not less than 20 acres may suffice for 100 patients where suitable land is difficult to obtain or the cost of land is high. In all cases an area of at least one-fifth of an acre should be allowed per patient. The site should be moderately elevated and preferably slope gradually to the south and be protected on the north and east by high ground, preferably wooded. In some districts protection from westerly and south-westerly gales may be desirable. The subsoil should be dry. This must be secured if necessary by proper drainage, but a site requiring extensive drainage should, as a rule, be avoided. If house drainage into a public sewer is impracticable, the site should be suitable for the provision of an adequate sewage-disposal system. An abundant supply of pure water should be available. Lastly, the site should, if possible, be within easy reach of a railway station, thus saving cost of carriage for construction and subsequent maintenance of the institution. Further, it is undesirable that patients who are acutely ill should be unduly remote from their relatives.

Buildings.—In residential institutions for the treatment of pulmonary tuberculosis the following provision will be required: (1) Patients' sleeping accommodation; (2) kitchen, dining-hall, and offices; (3) staff block containing quarters for resident medical officer, matron, and staff; (4) outbuildings, ncluding laundry, boiler-house, disinfector, sputum destructor, mortuary, etc.

The planning of the institution will depend on the stage of disease of the tuberculous patients proposed to be admitted.

Group A. *Cases in which permanent improvement or recovery may usually be anticipated.*

Group B. *Cases in which only temporary, though possibly prolonged, improvement may be anticipated,* including patients who may be expected to recover considerable ability to work, as a result of protracted treatment; or admitted for a short term for educational treatment; or with advanced disease, many of whom improve greatly under institutional treatment.

Group C. *Advanced cases requiring continuous medical care and nursing.*

Group D. *Cases requiring special observation* (for diagnosis, or determination of form of treatment).

"Emergency" cases, e.g. patients with hæmoptysis, etc., may come within any of the above groups.

The term *sanatorium* is used to indicate an institution mainly devoted to the reception of patients in Group A, the term *hospital* for patients in Groups B, C, and D, and the term *combined institution* for patients in all four groups.

The *combined institution*, in which there are separate rooms or pavilions, is most suitable for areas with a population too small to require the provision of 100 beds for patients in Group A. A combined institution should be so situate as to secure fairly easy access of relatives to patients acutely ill, while giving good local conditions for patients in Group A.

Separate provision should be made for children, though they may be accommodated on the same site as adults.

The *sleeping accommodation* provided in residential institutions for the treatment of pulmonary tuberculosis is commonly of one or more of the following types, viz. (1) single-bedded rooms, (2) two-bedded rooms, (3) beds on both sides of a ward as in the ordinary isolation hospital, (4) shelters.

Single rooms are desirable for patients who require a considerable amount of nursing, whether in

Groups A, B, or C. These rooms should be situated in the special nursing section.

Shelters, single- or double-bedded, are suitable for patients in Groups A and B who are able to be up and about all day. Single-bedded shelters may also be useful for doubtful cases sent for diagnosis (Group D), and for training patients with a view to the subsequent use of shelters at home. Owing to difficulties in supervision and administration it is undesirable to have a large proportion of the sleeping accommodation in shelters, and such provision should not exceed 10 per cent. of the total accommodation.

For a *sanatorium* about 20 per cent. of the sleeping accommodation for patients should be in the special nursing section; for a *combined institution* about 36 per cent. of the sleeping accommodation should be so placed. In a combined institution it is undesirable that any special pavilion or section should be used exclusively for patients with advanced disease.

Types of buildings.—There are three chief types of sanatoria:

(*a*) Pavilion system on ground floor (preferable).
(*b*) Ordinary hospital system (two or more storeys).
(*c*) Combination of (*a*) and (*b*).

General arrangements. *Space for patients and height of walls.*—The accommodation should provide a floor-space of at least 64 sq. ft. for each patient; the distance between the centres of the heads of any two adjoining beds should not be less than 8 ft. Patients' rooms should not be less than 8 ft. 6 in. high; wards should be higher, but may be carried partly into the roof and ventilated by openings in the gable end. Doors should be made on the "stable door" pattern, so that in inclement weather the lower portion may be closed while the upper portion is left open. They should be constructed in the form of French casements with a clear opening of not less than 3 ft. 6 in., so that beds may easily be wheeled through them. Windows should preferably be of the casement pattern and be hung "to fold" without mullions.

Baths should be provided on a scale of one to 12 patients. Spray baths may also be provided. There should be at least one water-closet for every 12 patients. Hospital slop sinks should be provided in the special nursing pavilion. Ample storage room is necessary for linen, clothes (drying, etc.), and lockers for boots and shoes.

Kitchen and dining-hall accommodation.—The block containing the patients' dining-hall and the kitchen for patients and staff should preferably be a one-storey building, which should be placed near to the administrative block and to the rooms for patients requiring special nursing.

The consulting-room, dispensary, and laboratory, which should be centrally situated, may also conveniently be included in this block.

The *staff block* should be designed for economical service and administration. A sanatorium with 110 beds requires medical officer's quarters, offices, matron's quarters, dining-room for nurses, bedroom accommodation for the nurses and servants. Each nurse should have a separate bedroom of an area of about 100 sq. ft. Usually one nurse will be required for 12 patients. Baths and water-closets should be provided in the proportion of not less than one to each 12 nurses or servants.

Outbuildings.—The laundry should consist of receiving room and washhouse, drying-room, and ironing and delivery room. Mortuary accommodation may be provided in the same block.

Special provision should be made for the sterilization of sputum and for the cleansing of sputum cups. Unless suitable arrangements are available elsewhere, some form of disinfector for clothing and bedding should be provided.

Heating and lighting.—An ample and constant supply of hot water is desirable, and the system should be capable of easy extension. For general heating, a system of low-pressure hot-water heating will be found most economical. Electric lighting should be employed where available. It may be necessary to use coal gas, acetylene, or petrol air gas; these illuminants have been found to be fairly satisfactory for use in sanatoria if suitable fittings are provided and adequate precautions are taken against fire.

Construction.—Where, owing to local circumstances, the use of brickwork would be economical, cheap bricks may often be employed, faced externally, if necessary, with rough-cast or cement. Walls in exposed positions should be of hollow construction. In some districts other materials may be less expensive and may be employed, such as steel framing carrying terra-cotta slabs, or concrete slabs or blocks plastered internally and cemented externally, or timber framing lined internally with asbestic sheeting, or expanded metal lathing plastered with a hard-setting plaster, rough-cast, or coated externally with weather-boarding chemically treated. The roofs should be of simple construction, and may be covered with slates, tiles, or asbestic material. The floors of verandas should be of impermeable material.

The **Isolation Hospitals Act, 1893,** gives to County Councils limited power to secure the provision of isolation hospitals in their various counties. It applies to England and Wales generally, but not to London or to any county borough; other boroughs also are exempt, except by Order of the **L.G.B.,** if the population be less than 10,000 (according to the latest census), or by consent of the corporation if the population be 10,000 or more.

A *hospital district* may consist of one or more local areas; a "local area" includes an urban or rural sanitary district, or any "contributory place," and is constituted by Order of the County Council.

Procedure.—The County Council may take the initiative by directing their **M.O.H.** to report as to the hospital requirement of any part of their county, and acting upon his report; but they may also be set in motion by a petition from any Local Authority, or from twenty-five ratepayers in any contributory place. The next step is for the County Council to hold a local inquiry, after which they make an Order constituting the hospital district and defining its extent. No local area can be included in a hospital district without the consent of its Local Authority, if it already has (in the judgment of the County Council) adequate accommodation; nor must a hospital district be formed for one local area only, or for one or more local areas within the same **rural** sanitary district, without the consent of the **S.A.**, unless the County Council are satisfied that the **S.A.** are unable or unwilling to make suitable provision for the purpose. The Order constitutes a hospital committee consisting of local representatives, but if a grant be made out of county funds the committee may consist wholly or in part of county councillors. The Order further gives the committee power to provide and maintain a hospital; and apart from this they are authorized by the Act to make temporary arrangements for isolation, and to establish district hospitals in cottages or small buildings. They may also (subject to any regulations made by the County Council) undertake the training of nurses, and may charge for their attendance outside the hospital. Every hospital is to be provided with one or more ambulances, and must, if practicable, be "in connexion with the system of telegraphs."

The County Council have the power of inspecting any such hospital, and of raising money by loan for the purposes of the hospital.

Expenses.—"Structural" (e.g. site, building, furnishing, extensions, etc.) and "establishment" (e.g. maintenance of hospital, salaries, etc.) expenses are borne by the several local rates of the constituent local areas, in proportions to be fixed by the Order. The costs of conveying, removing, feeding, medicines, disinfecting, and "all other things required for patients individually, exclusive of structural and establishment expenses," are termed *patients' expenses.* For ordinary non-pauper patients they are to be paid by the Local Authority out of the rates of the local area from which the patient came, but the Guardians are responsible if poor-law relief had been given at or within a fortnight of the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, etc., on such terms ("special patients' expenses") as the committee may appoint.

The **Isolation Hospital Act, 1901,** provides that a **S.A.** having possession of a hospital for the reception of the sick may, with the sanction of the **L.G.B.**, transfer it to the County Council for appropriation to a district under the Isolation Hospitals Act, 1893, as an infectious diseases hospital, and the County Council may contribute to the expenses of such a hospital. Minor amendments and definitions are included in the Act.

CHAPTER IX

DRAINAGE AND REMOVAL OF REFUSE

THE waste matter from households comprises (1) liquid refuse, including water used for washing, and slop-water; (2) ashes, and vegetable and animal refuse; and (3) excreta.

Drainage is necessary for dealing with the first, and some system of dry removal for the second. The excreta may be disposed of in conjunction with the former ("water-carriage"), or with the latter (privy-middens, ash-closets), or independently (earth-closets, privies, or pail-closets without admixture of ashes). A water-carriage system in a dwelling consists essentially of (*a*) sinks for the disposal of waste water, and the necessary drainage for carrying off bath and lavatory water; and (*b*) urinals and water-closets with their necessary drainage. There is, of course, also the necessity of carrying off rain water from the house, curtilage, and subsoil. Before dealing with these requirements it will be well to consider drainage generally.

Drainage.—A drain means any pipe used for the drainage of one building or premises. A sewer is a drain receiving the drainage of two or more premises. The former is vested in the owner, the latter in the **S.A.**

Drains are intended to remove from the house the liquid and much of the solid filth that is produced within it, and they should be so constructed that in no circumstances can their contents, liquid, solid, or gaseous, escape from them at any but the points specially provided for this purpose. This result is attained by the choice of proper materials for their construction and by sound workmanship, by trapping all inlets so as to prevent the egress of drain-gases, and, lastly, by efficient ventilation at suitable points.

A **trap** in its simplest form is a mere bend in a pipe which retains water and thus prevents air from passing through it. For this purpose it is only necessary that the bend shall be sufficient to place some portion of the upper surface of the pipe below the water level, the *seal* of the trap being the difference between the surface of the water and the depression at this point. Thus, in the diagram (Fig. 28), the seal is the water between *a* and *b*.

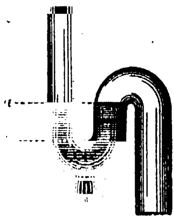

Fig. 28.—Siphon trap (S-trap) with access screw-plug for cleansing.
a, *b*, the seal.

A water-seal alone will not always prevent the passage of gases and particulate matter through it. Gases in the drain can be absorbed by the trapping water and given off from its upper surface. Ammonia has been found to become perceptible through an unbroken trap in fifteen minutes. Moreover, when the water remains stagnant, bubbles of putrefactive gases may be formed, and, by their bursting, particulate matter may be discharged. Occasional changing of the trapping water is necessary, and the drain must be ventilated to prevent its air contents from becoming too foul, or subjected to so much pressure that the water-seal is forced. A trap to fulfil all these requirements must be self-cleansing and must maintain an effectual seal between the drain and the outer air. For the former purpose it must be free from all angles and corners that can retain filth ; for the latter it must have a water-seal not less than 1½ in. deep.

The seal is liable to be broken by a number of circumstances. First, pressure within the drain may force its air contents through the trap. This can be prevented by ventilation of the drain. Secondly, if the momentum of the water discharge be great, the water in the trap may be driven out. This can be obviated by shaping the trap so that the water-holding portion is contracted, and the descending arm is larger and square at the outlet. Thirdly, if the descending arm is long and runs full, it may empty the trap by siphon action. This can be avoided by ventilating the top of the trap beyond the seal. Fourthly, the same result will sometimes follow when two or more pipes are connected together, the discharge from one sucking out the water from the trap of the other. This can be prevented in like manner. Lastly, the seal may disappear by evaporation, if the trap is little used.

The **drain** must be laid with a sufficient fall for the purpose of enabling it to clear itself of its solid and fluid contents, and it is generally accepted that this should be 1 in 40, giving a velocity of flow in a 4-in. drain of about 3 ft. per second.* Further, in discharging into a sewer, the drain should be connected with the lower half-diameter of the sewer.

The drain should be constructed of glazed stoneware pipes with cemented water-tight joints, or preferably, if the drain be beneath a building, of iron pipes (of which the interior has been coated with Angus Smith's solution) jointed with lead. In all circumstances the drain should be laid on a bed of concrete, and if it be made of any other material than iron the whole drain should be embedded in concrete. It is customary to use drains having a diameter of 6 in., but a 4-in. diameter is frequently sufficient for houses of moderate size. It should never be less than this.

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* Drains should be laid in straight lines as far as practicable and at even gradients. They should be smooth, water-tight, air-tight, and self-cleansing. For a 4-in. pipe the gradient should be 1 in 40; for a 6-in., 1 in 70 ; for a 9-in., 1 in 100 ; and for a 12-in., 1 in 150.

As a general rule, the drain should not be laid beneath a building, but in the case of terrace houses it is often impossible to adopt any other plan. In this situation the drain must be laid in a direct line beneath the building and be embedded and covered in concrete not less than 6 in. thick; the top of the drain at its highest point must be not less than a distance equal to the full diameter of the drain below the surface of the ground under the building. Means of access should be provided outside the house.

An important point in connexion with drain construction is the prevention of air from the sewer passing into the drain, or from the drain into the house. The former of these risks is guarded against by the insertion of a trap in the drain (*interceptor*) as near as possible to the point of its connexion with the sewer. Such an interceptor is usually provided with a "raking arm" into the drain. The drain should be ventilated immediately on the house side of the trap, by a shaft carried up above the ground-level; this will serve a double purpose, by admitting fresh air into the drain, and also affording a free outlet in case the trap is forced by pressure of sewer air. The opinion appears to be gaining ground that if drains were properly laid in concrete, and if the ventilating pipe of every house drain (whether soil-pipe or not) acted as a ventilator to the sewer, the amount of foul air escaping would be so thoroughly and widely distributed as to create no nuisance; and that the interceptor may retain fæcal matter and even cause stoppage of the drain, especially if the gradient be slight (*Departmental Committee on Interceptors*, 1912). It should be added that, as a rule, bye-laws require an interceptor, with access thereto. A more complete and necessarily a more costly arrangement is that of an *inspection chamber* at this point (Fig. 29); the drain is continued through this chamber in earthenware channels, and the arm in the trap, which is intended to allow the drain to be cleared between the trap and the sewer, is extended into the chamber. Branch drains are connected with the main channel by branch channels in the floor of the inspection chamber.

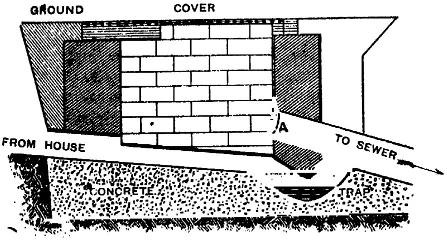

Fig. 29.—Disconnection (inspection) chamber.
A, "raking-arm," closed by a cap.

In connecting drains with one another, no right-angle joints must be formed, either vertical or horizontal. They must be made to join obliquely in the direction of the flow.

The second risk, that of air from the drain entering the house, is guarded against (1) by ventilation of the drain; (2) by trapping all inlets to the drain, except those required for its ventilation; (3) by trapping *and disconnecting* all *indoor* drain inlets; (4) by proper jointings and efficient plumbing (Fig. 30).

The proper ventilation of the drain is secured by continuing the soil-pipe in its full diameter above the level of the roof. The openings referred to must be covered with suitable gratings to keep out leaves and dirt, and to prevent birds from building nests in them. The sectional area of the ventilating pipe should not be less than that of the drain which it ventilates.*

Soil-pipes should be situated on the outer walls of the house, and their junction with the drain, often a weak point in construction, will then be outside the house. If through any accident the junction of the soil-pipe with the drain should be opened, the escape of gas will be into the open air.

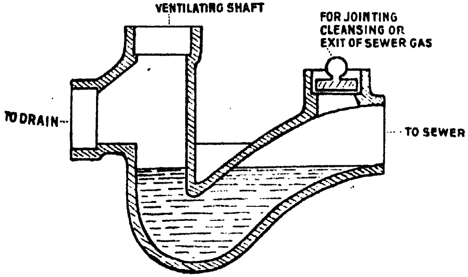

Fig. 30.—Disconnecting and ventilating trap.

Whether the soil-pipe is used for the purposes of ventilation or not, bends in its course should be avoided as far as possible. As a general rule, the diameter should be 4 in. Iron and lead are both used; lead is more expensive but more durable, and free from joints that may become loose. Rolled (i.e.

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* The *requirements of a good house-drain* are therefore—(1) drain-pipes of suitable material and size (4-6 in.), with smooth internal surface, (2) adequate fall (1 in 40 to 1 in 60), (3) connections or branches never at right angles, (4) effectively trapped and ventilated, and (5) with sufficient flush to cleanse.

seamless) lead is necessary if the soil-pipe is inside the house. The old practice of trapping the foot of the soil-pipe is inadmissible, since it prevents ventilation and impedes the escape of sewage. When the soil-pipe receives the discharge from two or more closets at different levels, it is necessary to guard against siphonage of the lower traps. For this purpose an *anti-siphonage pipe* (2 in.) is fixed from the trap of the lowest closet to a point in the soil-pipe above the level of the highest closet (Fig. 31).

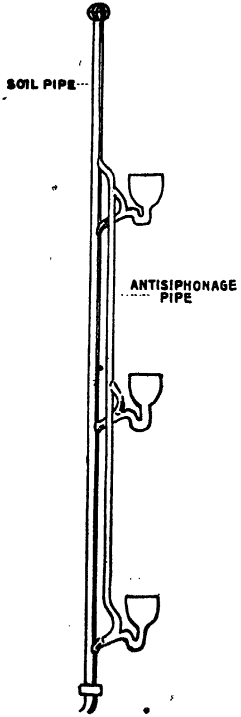

Fig. 31.—Antisiphonage pipe.

It is now necessary to consider the three sets of drainage arrangements which must form part of any modern dwelling, viz. the rain-water system, the waste-water system, and the water-closet system.

1. **Rain-water system.**—The protection of the house from rain-water is secured by a water-tight roof of impervious, smooth, hard, durable material, so jointed, fixed, and sloped as to allow water to

pass over its surface readily; gutterings and flashings leading to rain-water pipes discharging over open gullies; gullies and drain-pipes to carry water off curtilage, with ample provision for storm overflow. Where rain-water is collected from the roof for drinking purposes, care must be taken to secure that the surface from which it is collected does not consist of zinc or lead, and the receptacle in which it is collected must be kept clean and covered.

Drainage of the subsoil of a house is not necessary in all cases, but when the site is damp some provision of the kind should be made. The drain laid for this purpose should be at the depth of about 4–6 ft., should consist of suitable earthenware pipes, not less than 2 in. in diameter, with the joints left open, and laid to a proper outfall, preferably in the open air, but if into a drain connected with the sewer the connection should never be direct. The subsoil drain should always discharge into a trap, and should be ventilated at or near the trap by a shaft or upright pipe carried above the surface.

2. **Waste-water system.**—This system is arranged usually in conjunction with the rain-water system. The overflow of a cistern should simply be carried through an external wall to discharge in the open, so that no drain gases can enter the cistern, and waste of water from faulty apparatus is at once seen. But the foul-water wastes of sinks, lavatories, and baths must be differently dealt with. Slop-sinks used for disposal of urine must be treated as water-closets, but all other wastes should be made

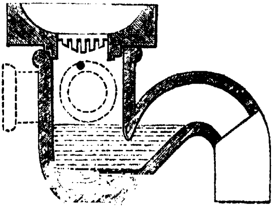

Fig. 32.—Yard gully.

to discharge over trapped gullies in the open air. Such *disconnection* renders it impossible for the air from the drain to enter the house.

A suitable form of gully-trap is shown in Fig. 32. Here the waste-pipe discharges through a side opening beneath the grating, and above the water in the trap. The grating must be large, with a free opening kept constantly clear, or else the primary object of disconnection is lost. More commonly the waste-pipe pours *over* the grating, with more effective disconnection but some risk of splashing. Neither of these methods complies with the requirements of the Model Bye-laws that the waste-pipe shall discharge over a channel leading to a trapped gully grating at least 18 in. away.

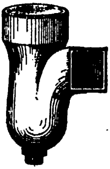

Fig. 33.
"Anti-D" trap.

Waste-pipes should always be trapped, and the trap situated as near as possible to the sink or bath. The interior of the pipe becomes coated with decomposing soap or fat, which is itself offensive; the higher temperature of the interior of the house leads to an offensive in-draught through an untrapped pipe, still more marked after the pipe has been heated by discharge of hot water.

A convenient form of trap is one shaped like an **S** (Fig. 28), and fitted with a screw at its lowest point, by the removal of which it is possible to cleanse the trap. Where the momentum of the water-discharge is great, a useful modification of the trap is that shown in Fig. 33, by which the unsealing of the trap is prevented.

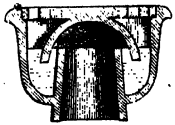

Fig. 34.—Bell trap.

From the trap the waste should be carried as rapidly as possible through the wall, and then descend to the gully. When the waste-pipe is long, or when two or more waste-pipes are connected, ventilation of the trap is needed to prevent siphonage, and is effected by an air-pipe passing from the top of the trap, beyond the seal, to the open air. The common "bell trap" shown in Fig. 34 is open to more than one objection: the depth of the seal is inadequate (about $\frac{3}{8}$ in.); it readily becomes choked with grease, being far from self-cleansing, and as a result the grating is often removed to let the water pass away, and on each such occasion the waste-pipe is untrapped.

The D-trap shown in Fig. 42 is the worst of all, as it readily becomes filthy, and always leads to the retention of a large amount of offensive matter.

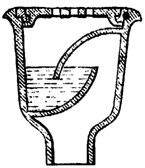

Fig. 35.—Antill's trap.

In large households the gully into which the scullery sink-waste discharges is liable to become choked by sand and grease (solidifying on cooling). In such cases frequent cleansing is essential. A "grease-trap" (i.e. a gully so constructed that the outflow of liquid is not prevented by solid accumulation at the surface or bottom), such as is shown in Fig. 36, is sometimes adopted.

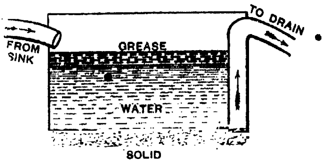

Fig. 36.—Grease-trap.

Wastes from sinks and baths in upper storeys are sometimes discharged into the head of a large pipe, which may or may not also receive rain water. Though disconnection is secured, the large pipe is liable to be fouled with soapsuds and grease. A better arrangement is to carry the waste directly to the gully, due precautions being taken against siphonage. A waste-pipe of 1½ in. diameter is sufficient even for baths, and if two or more be joined they may discharge into a somewhat larger pipe, a ventilating pipe being carried from the upper end of the common pipe to some convenient position above the level of the windows.

The *rain-water pipe* should not be used as a soil-pipe, or as a ventilating pipe to the drain. Thorough ventilation of the drain is most needed at times of heavy rain, when the rain-water pipe is least able to act in this way; and as the rain-pipe cannot be carried above the eaves of the roof, it often discharges its air contents too near to a window. For the latter reason this pipe should not be connected with the drainage system, but should be made to discharge over a trapped gully or a channel leading thereto. It is well that a waste-pipe in frequent use should discharge into the same trap, thus avoiding risk of unsealing by evaporation in dry weather.

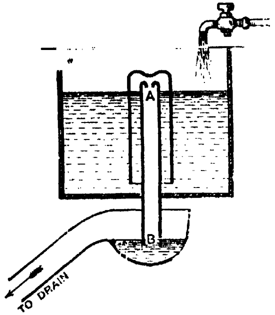

Fig. 37.—Flush-tank.

In small houses the ordinary discharge of liquid is usually sufficient to scour the drain and make it self-cleansing, but where necessary this can be supplemented by a *flush-tank*, periodically discharging its contents into the drain (Fig. 37). This is a cistern containing a large outer tube closed at the upper end and inverted over a small inner tube A B, thus forming a siphon; A B is open at the top, and passes vertically down through the tank, to dip slightly under the surface of water in a chamber below the tank, the water in this lower part being kept at the required level by means of a weir, practically forming a D-trap. As the water rises in the tank from the discharge into it of a tap or a drain, some of it eventually runs over the top of the tube A B, carrying with it air which is forced through the water at B, and cannot return; siphon action is started, and the whole contents of the tank are emptied into the drain.

Testing of drains and soil-pipes can be most effectually done by means of (*a*) the water test. For the purpose of testing the horizontal drain, a plug is inserted at that portion of the drain which is near the intercepting trap intervening between the drain and the sewer; the drain is then charged with water, care being taken to see that there is no leakage through or at the side of the plug, and the water is allowed to fill the drain to the top of one of the surface traps connected with it. At the end of from half an hour to an hour the maintenance or subsidence of the water level in this trap will show whether there is any leakage. In testing a large system of drainage it is necessary to take each section separately. In testing soil-pipes with water, the plug must be inserted at the bottom, and if several water-closets are connected with the same soil-pipe the trap of each must be plugged.

(*b*) Smoke pumped into the drains previously plugged in the same way serves also as a useful test. The process must be continued until the smoke is seen issuing from the soil-pipe or ventilating pipe, and if several of these are connected with the same drainage system it is necessary that each be plugged at the top as smoke issues from it until the whole system is charged, care being taken to prevent the smoke from being forced through the traps; smoke in these circumstances, when there is leakage, soon finds its way into the interior of the house.

(*c*) Peppermint was formerly used in the same way; 2 oz. or more of the oil was either poured down a soil-pipe with a pailful of boiling water, or down some trap situated outside the house connected with the soil-drain; the scent of the oil of peppermint found its way into the house in the event of defective pipes. Chemical "testers" such as Kemp's or Kingzett's are now commonly used. These are composed of some strong-smelling chemical, e.g. calcium phosphide, which, when moist, evolves phosphoretted hydrogen, and when the tester is washed into the drain over the trap the water soaks the paper fastener, and the spring being liberated the contents escape. If the drain be defective the odour escapes into the house in about fifteen minutes.

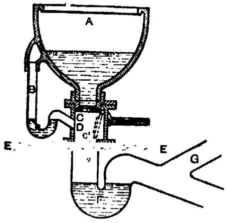

Fig. 38.—Valve closet.

A, basin : flushing-rim above ; B, trapped overflow ; C, valve, closed and open, C′ ; D, valve-box ; E E, safe ; F, trap ventilated at G.

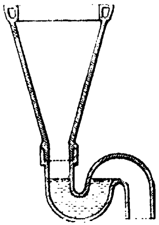

Fig. 39.—Long-hopper closet.

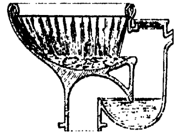

Fig. 40.—Wash-out closet.

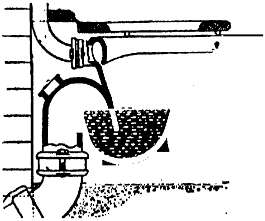

Fig. 41.—Wash-down or short-hopper closet.

3. The **water-closet system** consists of (*a*) water-closets and slop-closets, (*b*) urinals. These discharge

into the soil-pipe, to which reference has been made. The soil-pipe passes down the side of the house and becomes the house drain, which, after ventilation and trapping, is connected with the sewer.

The surfaces of the water-closet must be non-absorbent, and in its shape and capacity the basin must be able to receive the water that is discharged into it, and to allow all matter it receives to fall directly into water without soiling the sides. There are five chief kinds of water-closet:—

(*a*) The *pan* closet.
(*b*) The *valve* closet.
(*c*) The *hopper* closet.
(*d*) The "*flush*" closet (*wash-out* or *wash-down*).
(*e*) *Trough* closets.

In both the *valve closet* (Fig. 38) and the *wash-out* patterns (Fig. 40) water is held in the basin independently of that in the trap below. In the one case it is held by a movable valve, in the other by a fixed dam, over which the contents are carried by the flush. This latter form is not wholly satisfactory. In the plug closet the valve or dam is replaced by a solid plug, which works vertically in a side-chamber similar to that shown in Fig. 38.

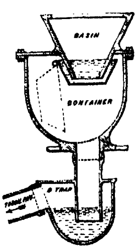

Fig. 42.—Pan closet, with D-trap.

Hopper closets are of two kinds: the basin of the old *long hopper* (Fig. 39) is from its shape and construction liable to become filthy, and it has in addition usually an ineffective flush; the *short hopper* or *wash-down* (Fig. 41) is a "flush" closet and is free from objection. It possesses the advantage of a large water surface in consequence of the form of the trap being such as to allow the water to stand high in the basin. In addition to this there is a deep water-seal, and the cleansing of the trap is greatly facilitated. It is the most satisfactory form now in use. There is at present a wholesome tendency to dispense with all unnecessary woodwork and fittings, and to reduce the closet to its simplest form.

The old *container closet*, or *pan closet* (Fig. 42), is especially objectionable, and is prohibited by the Model Bye-laws. The basin discharges into a large receptacle, which becomes foul and, every time the valve is opened, allows polluted air to escape.

The apparatus, of whatever kind, should be provided with a flushing rim which directs the water over the whole surface, and maintains it in a state of cleanliness. It is essential that the flush should be of sufficient volume (not less than two gallons), delivered with sufficient force (and for this purpose the pipe must not be less than 1½ in. in diameter), and properly directed so as to wash the basin effectually. The flush must on no account be taken from a service pipe or a cistern that supplies water for household purposes, but from a special cistern fitted with a water-waste preventer. Gases and even filth have been found to make their way from the closet basin up the (usually empty) delivery-pipe.

It is unnecessary to discuss at any length the traps used in connection with water-closets. The **S**-trap is here again found to be a useful form, but liable occasionally to become unsealed when the momentum of the water-discharge is great; for this reason, therefore, the form of trap (Fig. 33) recommended in connexion with waste-pipes to obviate this difficulty is preferable. The **D**-trap is altogether inadmissible.

Water-closet traps are liable to become unsealed in the same manner as those of waste-pipes. Wherever two or more discharge into the same soil-pipe, ventilation of the traps is therefore necessary; the ventilating pipe from the trap of the lowest water-closet may receive the ventilating pipe of each above, and be finally connected with the soil-pipe above the highest water-closet; but, while this arrangement is permissible, it is frequently preferable to carry the antisiphonage or ventilating pipe independently above the roof.

A closet or bath on an upper floor is usually provided with a *safe* to receive any overflow or splashings. The waste-pipe from the safe may be treated in the same way as an overflow from a cistern, i.e. simply carried through an external wall, and made to discharge a few inches from the brickwork.

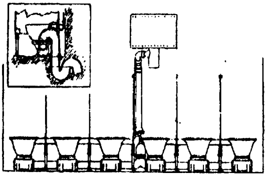

Fig. 43.—Trough closets (Doulton).
Elevation showing position of tank for ranges of six and over.

Trough closets (Figs. 43 to 46) are sometimes adopted in schools or factories. A long trough filled with water passes beneath the seats of closets placed side by side. At stated intervals the trough is flushed, automatically or by an attendant, and the contents are carried away to the sewer through a trap at the outlet end. An automatic flush may be effected by a tilting receiver placed at the upper end of the trough, and so arranged as to capsize and discharge its contents as soon as it becomes filled by a regulated stream of water; or still better by a flush-tank fed by a stream of water and discharging itself into the trough by siphon action as soon as it becomes full. In either case the frequency of the flush can be regulated by

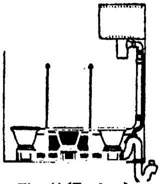

Fig. 44 (Doulton).
Elevation showing position of tank for ranges of three to five.

the supply of water. Trough closets are now obtainable with separate partitions and separate pans attached to one common discharge pipe (Fig. 46).

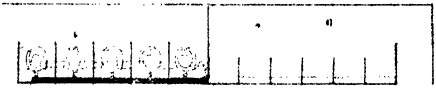

Fig. 45.—Cast-iron enclosures for trough closets and urinals (Doulton).

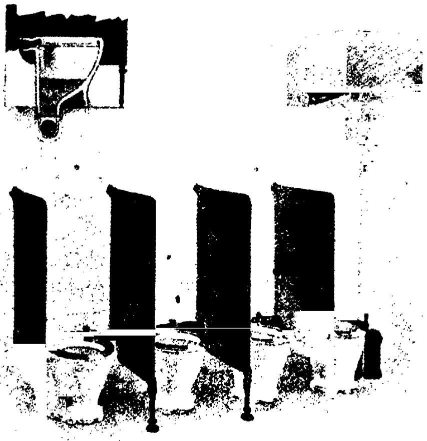

Fig. 46.—Isolated trough closets (Doulton).

In *waste-water closets* the flush is effected by the household waste-water, the object being, of course, to avoid the expense of a separate water supply. The drainage from a row of houses is conducted to a flush tank placed at the end of the row farthest from the sewer. From the tank a large pipe drain passes to the sewer, and separate closets are placed upon its course, the excreta simply falling through large vertical drain-pipes into the drain below, and remaining there until the next flush sweeps them away into the sewer. The drain has a siphon trap after passing the lowest closet, and a manhole or access chamber at the same point for use in the event of obstruction.

In like manner the waste-water of single houses has been utilized for flushing single outdoor closets. For closets of this type, which are known as *slop-closets*, the household waste-water, supplemented if necessary by the rainfall, is collected in a "revolver" or "tumbler," an earthenware vessel working on pivots, and so constructed as to overbalance when full, discharging its contents forcibly along the drain, and then swinging back to its former position. On the drain, beyond the tumbler, is a large siphon trap, and the closet consists of a wide vertical shaft over this, so that the excreta fall into the water of the trap and are carried away by the next flush.

The use of waste-water for flushing is attended with practical difficulties from the over-concentration of sewage, and the liability of automatic appliances to get out of order.

Intermediate between the water-carriage and dry systems come certain Continental and other methods which may be described briefly. The *fosse permanente* is a large water-tight underground pit, to which pipes from the closets conduct the excreta; the pit is emptied at long intervals by suction through hose into an air-tight cart. The *fosse mobile* is a closed movable tub placed outside the house, and connected with a fixed pipe that communicates with all the closets, etc., in the house; the tub is simply removed and replaced by another when full. In *Liernur's system* a number of closets are connected by means of iron pipes with an air-tight tank, which is at intervals exhausted of air, so that the excreta are drawn into it.

Dry systems of excreta removal, otherwise known as "conservancy systems," include *privies, pail-closets* (with or without ashes), *ash-closets*, and *dry earth-closets*. In some localities privies are called earth-closets, but this use of the term is misleading.

The *privy and ashpit*, or midden system, which is still employed in certain towns, and in most rural districts, aims at the deodorization and drying of the excreta by admixture with ashes. The best construction is that of a small water-tight pit, not drained but roofed over to exclude rain, and so arranged that the excreta and ashes become thoroughly mixed. For this purpose either the ashes must be thrown in through the closet seat, which may be hinged so as to be lifted *en masse*, or else a "shoot" or sloping slab must conduct one or the other to a common point. The floor should be smooth, and raised a few inches above the level of the adjoining ground. Very few middens fulfil these conditions, however.

The contents ought to be removed at fixed short intervals by the **S.A.**, and the work should be done at night or early in the morning so as to minimize the nuisance. Unfortunately it is still common to leave the emptying of ashpits to contractors, or even to the owners and occupiers, and the interval is frequently several months, instead of a week as prescribed by the Model Bye-laws. Privies alone, without admixture of ashes or other deodorants, are also met with. The receptacle should be small, and its contents frequently removed, but at best the system is more offensive than when ashes or earth are added.

Pail- or *tub-closets* are simply miniature privies, in which the pit is represented by a movable pail placed beneath the closet seat. The full pails are removed, and replaced by clean empty ones, at regular intervals not exceeding a week. Close-fitting covers should be used during removal of the full pails. There are several modifications of this system. On the "Rochdale system" the pails contain excreta alone, while in some towns the ashes and other dry household refuse are added; or the ashes are thrown upon a sifter, and only the fine ash falls into the pails; or the Goux system is used, the cleansed pails being lined with a dry, absorbent packing of compressed peat or like substance.

In Morell's cinder-sifting *ash-closet* the ashes are thrown in by a separate opening, and by a simple automatic arrangement are sifted, so that only the fine ash falls upon the excreta, the cinders finding their way to a separate chamber for further use as fuel. The receptacle is permanent, and in this respect resembles a privy rather than a pail-closet, but it is small and so arranged as to be readily emptied by a special opening. Taylor's closet is somewhat similar in principle, but the urine is collected separately.

Dry earth-closets have a small receptacle, fixed or movable, beneath the closet seat. Clean, dry earth (about 1½ lb.) is thrown upon the excreta, either by hand or by automatic delivery from a hopper, every time the closet is used. A constant supply of fine dry earth is needed, ordinary mould being the best, owing to its richness in nitrifying organisms. The contents may be subsequently mixed with dry mould in a drying-shed. Sand is less efficacious. (For method of working *see also* p. 226, footnote.)

Destination.—Water-carried excreta pass into the ordinary sewers, and their ultimate disposal will be considered in another section (p. 317).

Pails are emptied and cleansed at a central depôt, and are then ready for further use. Their contents are sent into rural districts as manure, either in the crude state or after conversion into "poudrette" by drying and other treatment. For the manufacture of poudrette the excreta (free from ashes) are heated in revolving cylinders, so as to drive off the moisture. Sulphuric acid is often added to fix the ammonia.

Contents of ashpits are commonly sent away at once into the country. The refuse of ash-closets or pail-closets is also available as manure.

The earth from earth-closets can be dried and used again and again, and finally restored to the garden or field. The organic matter disappears by nitrification.

Comparative advantages of water-carriage and dry systems. 1. *Hygienic.*—Water-carriage is by general consent the most satisfactory in houses of the better class, where cleanliness and freedom from effluvia are the main considerations, and due care in use can be relied upon. The excreta are at once carried right away from the premises. Water-closets may safely be constructed within the house, a matter of great convenience. The objection that the sewers receive the specific poison of enteric and other fevers may be met by the use of disinfectants, and has not yet been proved to be weighty. It has been urged that indoor water-closets afford facilities for the entrance of sewer-air, especially in the case of obstruction of the sewers by floods or other causes. Indeed, it has been observed in more than one enteric outbreak that the inmates of large water-closet houses upon high ground suffered more than the poorer inhabitants of lower districts with outdoor closets. This danger, however, can scarcely occur unless there is grave defect in construction or management, and it extends equally to indoor sinks. As applied to poorer dwellings water-closets often fail. Owing to carelessness or misuse, the mechanism becomes deranged, or flushing is neglected, and the drains become choked by bulky objects improperly introduced into them. Automatic flush closets, trough closets, and even slop-closets, if kept under supervision, are to a great extent free from this objection, since they are not liable to become deranged by carelessness on the part of those using them. Water-closets of ordinary construction are made serviceable, even in houses of the poorest class, by careful supervision on the part of the **S.A.** Neglect of hand flushing may be met by automatic mechanism connected with the door or the seat. The water supply of outdoor closets is liable to be stopped by frost, but this rarely happens if the cistern and pipes are properly cased.

Privies and ashpits are being abandoned in most towns, although still almost inevitable in country districts where there is neither efficient drainage nor organized scavenging. The retention of large quantities of excreta and other organic matter near dwellings is in itself objectionable, and the nuisance becomes great at the time of clearing out. It is probable that such an arrangement favours the spread of diseases that have relation to filth, and especially those in which the poison is contained in the excreta. The case becomes worse when, as almost invariably happens, the pit leaks and allows its contents to pollute the soil and the subsoil water. In 1908 the incidence of enteric fever in Nottingham (a pail-closet town) was—one case in 33 houses having midden privies, one case in 185 pail-closet houses, and one case in 722 houses having water-closets.

Pail-closets have the advantage of extreme simplicity, and cannot be deranged by carelessness or anything short of wilful destruction. Although not removed instantly, as in water-closets, the excreta remain near the dwelling for a few days only, instead of putrefying for weeks or months as in middens. The weekly or semi-weekly visits of the scavengers ensure a certain degree of cleanliness, apart from the mere substitution of cleansed pails. It is claimed that in the event of such diseases as enteric fever occurring, the pails and their contents can be disinfected; unfortunately not all the infective matter is thrown into the closet, and at best its disinfection in any true sense would be difficult; but it is quite possible to adopt the simple precaution of supplying specially marked pails to infected households, and cremating the contents of such pails when collected. Pail-closets that receive excreta only are inevitably offensive, however frequently changed. The addition of ashes lessens the effluvia, and the average amount of ash produced by an artisan household is found to be sufficient for the purpose.

Dry earth-closets are convenient and free from effluvia. The difficulty of ensuring a constant supply of suitable dry earth, and of removing the products, has hitherto prevented their adoption in towns. In rural districts, where these difficulties do not exist, they offer great advantages, but can only succeed when used with care and kept under supervision (*See* p. 225.)

2. *Economic.*—Water-carriage involves some cost, either to the individual or to the public, in the extra consumption of water, although this objection does not apply to those systems in which the flushing is effected by the household waste-water. Drains and sewers have to be provided in any case, so their cost cannot be charged to the account of water-carriage systems. The increased volume of sewage in water-closet towns or districts is far less material than is generally assumed, and forms at most only a small fraction of the enormous volume derived from rainfall, soil drainage, household waste-water, trade effluents, and other sources. It has been found that the addition of water-closet sewage scarcely alters the chemical composition of the average sewage of a town. Hence the necessity of treating the sewage by irrigation or other means is quite independent of the admission of water-borne excreta to the sewers.

Water-carriage obviates some part of the expense of the scavenging required by the pail-closet system, but there must still be a costly organization for collecting the dry household refuse, which, without the addition of excreta, is an unsaleable commodity, and further expense is therefore incurred in disposing of it after collection.

A similar objection is often urged from the theoretical side, namely, that the enormous dilution of excreta by water renders it difficult or impossible to recover them again for manurial purposes, and hence the soil is steadily impoverished by depriving it of what should naturally be returned to it in exchange for the crops that it yields. Vivian Poore's dictum was that the proper destiny of organic refuse is immediate burial just below the surface of the soil, and on this principle he objected to water-carriage. This argument has some weight as bearing upon the still common practice of pouring the sewage of towns into rivers or into the sea.

From the purely financial point of view it is to be said that the objectionable midden system probably costs less than any other.

The pail system involves a heavy initial outlay in buildings and plant, and an expensive staff to manage it efficiently. On the other hand, some part of the expense is recouped by the sale of manure, and a scavenging staff must in any circumstances be maintained for the removal of dry refuse. The market value of the excreta is greater if unmixed with ashes, but it is questionable if the gain is sufficient to compensate for the cost of a separate collection of dry refuse, which, as already explained, is unsaleable. The dry systems ensure the return of most of the solid excreta to the soil, but a great part of the liquid excreta, which are more important as fertilizers, goes with the household drainage in any case.

Reviewing the whole question, the privy system must be regarded as contrary to sound principles of hygiene wherever facilities exist for any other arrangement. Water-closets are most suitable in town, and water-closets or earth-closets in the country.

Removal of ashes.—Where water-closets, or pail-closets for excreta alone, are in use, the ashes and kitchen refuse have to be removed separately. Small covered tubs or boxes (preferably of metal) should be placed in a yard or outhouse, and emptied at short and regular intervals by the scavengers. Frequently, however, large "bins" or fixed "ashpits" are employed, the contents of which are allowed to accumulate for long periods.

Household refuse ought to consist of little more than ashes, the animal and vegetable refuse from the kitchen being easily burnt.

Trade refuse, from slaughter-houses, markets, fish and fruit shops, and many other sources, requires prompt removal. This duty is often left to the proprietors, who make private arrangements with farmers, etc., to remove the refuse for use as manure, or convey it at their own cost to some suitable place. It is difficult to ensure proper system and regularity unless the **S.A.** itself undertakes the task, and the same difficulty may occur in urban districts in regard to manure from stables and cowsheds. Under the Public Health (London) Act, 1891, s. 36^2, the local authority may by formal resolution prescribe frequent removal.

Road sweepings and the contents of street gullies have also to be dealt with.

Destructors.—Any kind of refuse which contains organic matter, but which cannot be at once disposed of as manure, should be burnt. The refuse is thrown in at the top of a furnace, and becomes dry as it sinks down; all organic matter is burnt off, and at intervals the mineral matter, or "clinker" (forming about 30 per cent. of the refuse burnt), is raked out below, to be used for road-making, filling up hollows, etc. In the best modern destructors the clinker is withdrawn in large slabs and freely slaked with water to prevent flaming when tipped. Silica and ferric oxide are the chief constituents of clinker, which is now much used for bacteria beds, mortar-making, etc. After the furnace is started, the organic matter in the refuse is usually sufficient to maintain the fire without the addition of other fuel.

Numerous forms of destructor are now in use. They consist of furnaces of a varying number of cells and are charged in different ways ("shovel fed," "top fed," mechanical charging, etc.). These furnaces are not infrequently multitubular, or fitted with Babcock & Wilcox boilers, and the necessary draught is obtained naturally or by means of fans or steam blowers. They may be divided into two chief groups, the "single-cell system" (e.g. Horsfall's, Fryer's, Warner's, Baker's) and the double-cell or continuous grate system (e.g. Meldrum's, Heenan's, Sterling's); there are, of course, various modifications. By the single-cell system is meant a destructor with a boiler between every two cells, so that there is no intermingling of the gases from two or more cells. It is desirable to have complete combustion in the cell itself, but if necessary the fumes can be passed through a second furnace.

Sewers are the drains of a community of houses. They may be required to convey—

(i.) *Household effluents,* including waste-water from baths, lavatories, sinks, and all liquid refuse and urine. Where there are water-closets, the volume of sewage is somewhat increased, but its composition is little altered. Latrines, etc., attached to works, schools, or public resorts may be included under this head.

(ii.) *Trade effluents* of all degrees of impurity, from the comparatively pure water from condensers to the foul effluents from dyeworks.

(iii.) *Water used for public purposes*, e.g. watering streets, fountains, public urinals, baths, etc.

(iv.) *Rainfall*, of which the first portions (especially road-washings) are extremely impure.

(v.) *Subsoil water*, and even small natural streams.

Modern sewers, like house drains, are impervious tubes, oval or round in section. Their size varies according to requirements, say from 9 in. to 12 ft. in diameter. If the diameter is not greater than 1½ or 2 ft., glazed earthenware pipes set in cement are usually employed, laid in the manner described in speaking of house drains. Sewers of larger diameter than 18 in. are generally constructed of brick set in cement upon a bed of concrete, and are oval or ovate in section, so as to secure a better scour and less friction when little sewage is passing than if the section were circular. Sewers should be laid as far as possible in straight lines, with means of inspection and access at every change of direction. All junctions should be obliquely in the direction of flow, and the tributary sewer or drain should have a fall into the sewer at least equal to the difference in their respective diameters. It is desirable that the rate of flow should be not less than 2 ft. per second, and 3 ft. is better. Hence the minimum gradient should range from 1 in 250 to 1 in 750, according to the size of the sewer. The gradient should preferably be uniform, except at angles and junctions, where it is desirable to allow extra fall.

Manholes should be provided at short distances, and at all important angles, junctions, and changes of gradient, to allow of access for inspection and flushing. Flush-tanks may with advantage be placed at the head of each sewer. Flushing is chiefly required in sewers with insufficient gradients, at "dead ends," and in hot dry seasons, when the flow is smallest and decomposition most rapid. It may be effected more or less automatically by means of flush-tanks, or by temporarily damming back the stream and then allowing it to escape with a rush, or by suddenly discharging a large volume of water into the sewer through a manhole. Little benefit is likely to result from the perfunctory "flushing" of sewers that is commonly practised, consisting as it does of simply pouring a small and inadequate volume of water into the sewer through a hose, at intervals of several weeks. There is little to be gained by the addition of "disinfectants" to the water used for flushing.

The **air of sewers** ("sewer gas") has no constant composition, and, if the sewer be properly constructed, well ventilated, and sufficiently flushed, may differ but little from outside air. Much depends upon the sewage being removed quickly, or, on the other hand, being allowed to stagnate and undergo decomposition. In the latter case the air of the sewer becomes foul; oxygen is lessened, carbonic acid increased, and there is much organic matter, together with variable quantities of marsh gas, sulphuretted hydrogen, and ammonium sulphide. The exact composition of the organic matter varies, but its properties are similar to those of the organic matter in respired air. Micro-organisms adhere to moist surfaces, and hence the air of well-constructed sewers is, on the whole, remarkably free from them, except near fresh-air inlets and at junctions, where splashing occurs. Neither bacteria nor other solid particulate matters are, under ordinary circumstances, given off from quiescent liquid surfaces; but if fæcal putrefaction occur the bursting of bubbles may recharge the air with them. Haldane found in the air of a well-constructed but unventilated sewer in Bristol 20 volumes of carbonic acid per 10,000, but only 2 micro-organisms per litre, half of which were moulds; and Lawes and Andrewes demonstrated that the air of well-constructed London sewers contained fewer bacteria than the air of the street above, and the species found were mostly not of sewage origin. It thus becomes probable that sewer gas can rarely, if ever, convey pathogenic organisms. Recent investigations by Andrewes and Horrocks have, however, shown that no definite or final statement can be made on this point.

Air contaminated by sewage emanations may occasionally be a cause of diarrhœa and other gastro-intestinal disturbances, and of certain forms of sore throat. Anæmia, depression, and general ill-health may result from protracted exposure to such an atmosphere. Cholera, enteric fever, pneumonia, erysipelas, puerperal fever, and diphtheria have a much heavier incidence, both in numbers and severity, upon persons exposed to these conditions. It is not necessary to assume an origin *de novo* in such cases, or even in the case of diarrhœa and sore throat, the evidence being consistent with the supposition either that the specific poison is sometimes carried by such emanations, or that their effect is merely to predispose to the disease. There is no evidence of any specific relation between sewer gas and smallpox, measles, or whooping-cough.

Men working in well-ventilated sewers are not found to suffer any ill effects, but if ventilation is wanting they are liable to ophthalmia and to syncopal or apoplectic attacks. It is said that venereal disease is greatly aggravated by this employment. Meat, milk, and other food substances readily decompose if exposed to sewage emanation.

Ventilation of sewers.—Foul gases are given off by sewers, more especially if, from insufficient gradient or obstructed outfall, they become stagnant or "sewers of deposit." Hence it is necessary to provide means of vent or ventilation in order to avoid the risk of the pent-up gases forcing their way into houses through traps.* For this purpose openings are provided at intervals, which should not exceed 100 yards. Some of these openings act as inlets, others as outlets, and the latter only, of course, are liable to be offensive. The conditions that determine the direction of the currents of air are complex, including force and direction of wind, internal and external temperature, volume and velocity of sewage, etc., so that the result cannot be predicted, and is not even constant in the same sewer. Speaking generally, the tendency is for the air current to pass in the reverse direction to the sewage—that is, from a lower to a higher level—so that the highest openings are most liable to be outlets, and the lowest to be inlets. Nevertheless, every opening may at different times act both parts.

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* In Bristol the sewers are not ventilated. The house-drains are, however, provided with interceptors, and all street gullies are trapped.

The plan usually adopted is to provide grated openings in the roadway, leading directly to the sewer beneath, a cage being suspended immediately beneath the opening, to catch any solid débris that may fall through. It was formerly customary to place trays of charcoal in the openings in order to deodorize the sewer gases, but the charcoal obstructed the opening and soon became inert. To obviate annoyance from effluvia at outlets, ventilating shafts (in substitution for these openings) are often attached to houses or even to trees; these shafts should be, but rarely are, of sufficient calibre efficiently to ventilate the sewer. Sometimes factory chimneys are utilized for this purpose by carrying the vent into the stokehole or chimney. Another device (Keeling's) is to ventilate the sewers through hollow lamp-posts with gas jets inside serving to create a strong upward current and (it is claimed) to destroy all effluvia.

If carried out on a large scale these special arrangements are costly. It is contended by the advocates of simple openings at the street level that the true remedy for offensive outlets lies in proper construction and flushing of sewers, and increasing the number of openings—that is, in approximating to the condition of an open sewer. Some authorities rely upon ventilating the sewer by means of the vents of each house-drain connected (*see* p. 287).

Rain and subsoil water.—If the sewers are water-tight, as they should be, the subsoil water cannot gain access to them, and separate provision must be made for draining the soil, although a certain quantity of water flows away along the comparatively easy track outside the sewer. Sometimes provision is made for this by leaving a space beneath the sewer for the ground-water to pass along.

It is becoming customary to exclude also the rainfall from the sewers, and thus avoid dilution of the sewage and sudden changes in volume, which add to the difficulty of treating it by precipitation or filtration. The first washings of the streets are very foul, and should be admitted to the sewers. When the "separate" system is adopted, the rain-water is taken away by another system of drains, which may with advantage be permeable, and so available for draining the subsoil.

Capacity of sewers.—In towns only a comparatively small surface of ground is pervious, and almost all the rainfall rapidly makes its way to the sewers. Hence in planning the size and gradients of sewers it is necessary to provide for the immediate removal of the maximum hourly rainfall, say, 1 inch per hour *plus* the maximum volume of sewage from other sources.

Parkes gives the following formula for calculating the discharge from a sewer :—

$$V = 55 A \times \sqrt{2DF}.$$

V being the discharge in cubic feet per minute,

A, the section area of the current,

F, the fall, in feet per mile,

D, the *hydraulic mean depth*, in feet. This is $\frac{1}{4}$ of the diameter of the pipe, if running full or half-full; in all cases it is equal to the section area of the current divided by the "wetted perimeter" — that is, by the length of the arc formed by that part of the section of the circumference which is in contact with the stream.

When a sufficient fall cannot be obtained, *Shone's pneumatic system* offers great advantages. The sewage is conducted to one or many central collecting tanks by gravitation through drains and sewers of ordinary construction, and is forced through pipes, leading from the tanks to the outfall, by means of compressed air. Thus difficulties arising from inequalities or from low level of districts to be drained can be overcome.

Composition of sewage.—This varies from day to day, and from hour to hour, since both solids and diluting water are inconstant in amount. There are variations according to season and weather, and trade effluents may be important factors. The admission or exclusion of rain-water makes a very great difference, but the presence or absence of water-carriage of excreta does not seem to affect the composition of sewage very materially. Broadly, it may be said that sewage consists of (*a*) domestic excreta and waste-water, (*b*) factory discharges and trade effluents, and (*c*) municipal waste-water from stables, streets, etc. The Royal Commission on Sewage Disposal (1908–12) found the average composition of sewage to be somewhat as follows:—

Constituent parts.	PARTS PER 100,000.		
	Very strong sewage.	Average.	Weak.
Ammoniacal nitrogen	13·41	3·58	2·49
Albuminoid nitrogen	1·75	0·91	0·55
Total organic nitrogen	3·87	2·25	1·39
Total nitrogen	17·53	5·85	3·89
Oxygen absorbed at 27° C. in four hours	17·99	11·27	6·53
Chlorine	13·57	9·16	6·58
Solids in suspension	42·10	29·40	26·70

From other sources it appears that the phosphoric acid amounts to about 25 and the potash about 15 parts per million. These proportions are, of course, liable to very wide variation.

It is calculated that in an ordinary population

$2\frac{1}{2}$ oz. of solid excreta and 40 oz. of urine, together containing 150 gr. of nitrogen,* are yielded per person per day, taking an average of all ages. This corresponds to about 10 lb. of ammonia per annum, and a theoretical manurial value of 6s. 8d., to which the constituents of the urine contribute six-sevenths, and the fæces one-seventh only. The manurial value of sewage is dependent upon the combined nitrogen, potash, and phosphoric acid. The annual amount of sewage per head of population may be taken as 100 tons, the theoretical money value as manure being about 17s., to which the dissolved matters contribute 15s., and the suspended matters only 2s. Sewage also contains variable quantities of household waste, rain and storm water, grit, gravel, sand, and, in some localities, manufacturing waste products.

Bacteria in sewage are chiefly denitrifying and decomposition organisms (p. 175). Houston found in London crude sewage at the Barking outfall an average of nearly 4,000,000 micro-organisms per c.c., and in one sample of domestic crude sewage 28,000,000. All kinds of species are present (bacilli preponderating) and there are many spores. The most common are *B. coli* (600,000 per c.c.), the Proteus family represented by the "sewage proteus" (100,000 per c.c.); *B. enteritidis sporogenes*, sewage streptococci, and liquefying bacilli. Pathogenic organisms also occur, but, owing to the struggle for existence, rapidly disappear. All the organisms required for bacterial assimilation are present in the sewage itself. The artificial bacterial treatment of sewage is an application of the principles of nitrification as stated by Schlœsing and Müntz.

Disposal of sewage.—In rural districts the household and other liquid refuse, if not turned into a ditch or watercourse, is usually conducted to a cesspool or collecting tank, from which it is periodically removed and used as manure. The former plan is bad in every respect. The latter is permissible if the cesspool is made water-tight and properly covered and ventilated, regularly emptied at suitable intervals, and situated at a sufficient distance from any house, road, or water supply. The annotated Model Bye-laws require a minimum distance of 50 ft. from any dwelling, and 80 ft. from any water supply. Sometimes the sewage is led to a pit, or "dumb-well," in porous soil, the solids being removed at intervals and the liquids escaping into the ground. This practice is dangerous if the pit is near to dwellings or water supplies, and is not free from risk of polluting water in any case. Simple irrigation is free from objection if well managed, even on the small scale. "Subsoil irrigation" may work well when the conditions as to soil and fall are suitable; the drainage is conveyed into a branching system of loosely laid agricultural pipes, which allow it to escape into the subsoil. The pipes are laid about a foot or more beneath the surface. It is often necessary to relay them at intervals, owing to deposit of grease and other obstructive matter, but this may to some extent be prevented by the use of flush-tanks and grease-traps at the house-end of the drain.

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* This is Parkes's estimate. Frankland's estimate, for adult males, is 250 to 300 gr.

The chief point is to expose the sewage to the influence of growing vegetation, not so much for the sake of utilizing it as of rendering it innocuous. Sewage applied to the surface is partly absorbed by vegetation, partly oxidized (nitrified) in the superficial layers of earth. The sewage passed into leaking cesspools or dumb-wells escapes both forms of purification, and simply pollutes the soil and the subsoil water.

The disposal of town sewage may be effected in a variety of ways. The oldest and simplest is to pass it without purification into natural watercourses, a plan still common. The sea affords a ready means of disposing of the sewage of coast towns. It is allowed to escape only with the ebb tide, and reflux is prevented by valves. If it is conducted by pipes sufficiently far out to sea, it may not be washed back by currents or by the returning tide to foul the shore. Such a degree of success is far from being the rule, and there are the further objections that the removal of sewage by this means is only intermittent, and that the sewage is (at best) wasted. To a certain extent organic impurities in streams are got rid of by oxidation and by the growth of plants and other organisms, but this possibility of subsequent partial purification cannot justify the gross pollution of a stream at any given point. The purification can rarely be complete, and in no case can there be any certainty of the destruction of specific pollution, a consideration that is especially important when the stream furnishes the water supply of districts lower down.

The alternative is to purify the sewage with the object of oxidizing or retaining its dissolved and suspended impurities, and allowing only the water (with, at most, harmless dissolved matter) to pass into watercourses or the sea. This may be done by *precipitation* (with or without *filtration*), *intermittent downward filtration* through land, *broad irrigation*, or *bacterial treatment*.

Precipitation processes aim at throwing down the organic matter chemically or mechanically, by the addition of a reagent to the sewage. For the most part their success in this respect is only partial, and they leave the ammonia and chlorides in the effluent. They are, however, particularly useful for sewage containing trade effluents. The reagents, dissolved or suspended in water,* are added to the raw sewage either in the sewers (Scott's and Conder's processes) or, more usually, in a conduit at the works. In either case the flow of the reagent is regulated as required, and it becomes thoroughly mixed with the sewage before entering the tanks. The settling tanks are large and are usually worked in series, the overflow from each into the next being over a broad shallow sill, so that only the comparatively pure upper water may escape. The current being very slight in the tanks, suspended matters are gradually deposited, accumulating at the bottom in the form of sludge, which is periodically cleared out, dried, and sold as manure, or dug into the ground, or (in Scott's process) burnt into cement. A similar subsidence takes place if no precipitant is used, but the dissolved organic matter remains in solution, and the settlement of the suspended matter is much slower and less complete. A good precipitation process will rapidly clarify the sewage by removing all, or nearly all, the suspended impurities, and will, moreover, carry down a greater or less part of the dissolved organic matter. The effluent will be fairly clear, but will contain the chlorides and certain other salts, ammonia, and more or less of the dissolved organic matter. It is therefore necessary to subject the effluent to further treatment—that is, to filtration—in order to oxidize the remaining organic matter.

Precipitation affords no guarantee of the removal of microbes, pathogenic or otherwise, and has the further disadvantage in that it creates large quantities of sludge. Sludge may be pressed and disposed of as marketable manure; or deposited in the sea; or burnt, or destroyed by distillation; or the grease may be extracted for sale.

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* In the alumino-ferric process, cakes of the reagent are laid in the sewage current and dissolve slowly.

Many of the precipitation processes described in textbooks have been abandoned on account of cost or want of efficiency, and have now only an historic interest. *Lime* is by far the most generally employed, either alone or in conjunction with other reagents. It has been used together with clay (*Scott*), calcium phosphate (*Whitthread*), magnesium chloride and tar (*Hillé*). The "Amines" process consists in adding lime, together with a little herring brine. The latter, by virtue of the trimethylamine and other ingredients (aminol), acts as an antiseptic. The effluent does not decompose, and yields no microbes on cultivation. The precipitation is rapid. Lime with ferrous sulphate, ferric chloride, or aluminium sulphate gives a bulky precipitate of the respective hydrate, which entangles and carries down organic matter with it. Lime with ferric sulphate has been a very successful precipitant. Crude aluminium sulphate, made by acting upon clay or shale with sulphuric acid, is Anderson's (and also Bird's) precipitant; and sulphuric acid with mineral phosphate of alumina is the basis of Forbes and Price's process. Spence's "alumino-ferric" contains a very small proportion of iron salts. The "A B C" process consists in adding alumino-ferric, blood, clay, and charcoal. The sludge is formed into cake and sold as "native guano."

Another precipitant is "ferro-zone," made by acting with sulphuric acid upon "polarite," described as a specially prepared ore of iron. The effluent is filtered through a bed of polarite. Yet another iron process, differing from the rest in being applied at the *head* of the sewer or house drain, is Conder's, in which a regulated quantity of ferrous sulphate is added constantly and automatically by means of a stream (of water or sewage) passing through a vessel ("ferrometer") containing crystals of ferrous sulphate. It seems to be successful in preventing decomposition and effluvia, and in keeping the drains free from deposit. A saturated oxychloride of iron is used as a precipitant, in the ordinary way, in the "Clarine" process. Use is sometimes made of chalybeate waters for precipitation purposes.

Webster's electrolytic process adds iron indirectly. The sewage is made to flow through a series of tanks in which it is exposed to a powerful electric current passing between electrodes consisting of iron plates. Ferrous hydrate is continuously formed, and reacts at once in the nascent condition upon the sewage, causing a rapid and fairly complete precipitation of solids. A clear and slightly greenish effluent results, which is remarkably free from microbes and has little tendency to secondary putrefaction. In the Hermite process electrolysed sea-water is employed (as at Guildford).

In the black-ash process, a waste product from alkali- and soap-works is used as a precipitant. This refuse contains calcium sulphide, which by exposure to air is partially oxidized into calcium sulphite and hyposulphite. The prepared black-ash is used together with lime.

Lime processes in general yield an alkaline effluent, which has a tendency to "secondary decomposition." A lime effluent that is bright and clear on leaving the works will often be found to become turbid and offensive if its run can be traced for a few hundred yards without excessive dilution by other water.

Sterilization of sewage or effluent may be accomplished by chloros, heat, or ozone.

Precipitation and filtration.—Many of the precipitation processes require to be followed by filtration.

Among artificial filtering media, employed after precipitation, are various forms of carbon, ferruginous materials, and coke or burnt "ballast." All of these, like land filters, serve mainly as a nidus for the aerobic nitrifying organisms; their efficiency depends largely upon proper management, and especially due aeration. The flow should be intermittent and not too rapid. Coke is widely used. Garfield finds that fine coal filters give excellent results, and possibly the non-porosity of the particles is an advantage. Ferruginous materials include "polarite," "magnetite," and "magnetic carbide"; they should be covered with a layer of sand, renewed at intervals.

By filtration it is sought to remove the suspended matters, and to oxidize the organic matters and ammonia. The effluent should contain only chlorides and other dissolved mineral salts and nitrates, but some free and albuminoid ammonia is always found upon analysis.

Intermittent downward filtration may be defined as "the concentration of sewage at short intervals, on an area of specially chosen porous ground as small as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance," the flow of sewage being suspended from time to time in order to allow the filter to become charged afresh with oxygen from the air.

Land filtration requires a porous soil, underdrained by porous pipes at a depth of from 4 to 6 ft. The sewage is distributed over the surface by means of branching carriers or trenches, controlled by sluices, so that each portion of the ground in turn receives the sewage for a few hours, and each has intervals of rest. The soil is raised in ridges, upon which vegetables are grown, the sewage flowing along the furrows between the ridges. The utilization of the sewage is a minor consideration; but vegetation is useful in absorbing and assimilating the organic matter. This method is relatively costly, and requires 1 acre of land to every 1,000 of population. On suitable soil 1 acre can purify 30,000 gallons of domestic sewage in twenty-four hours. Land-filters planted with osiers (osier-beds) are sometimes employed for the purification of village sewage, or for the occasional treatment of storm waters that cannot be dealt with otherwise. The osiers absorb water and sewage matter freely; but constant care is needed to prevent choking of the surface-soil, or of the sub-drainage.

Broad irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied." For broad irrigation, as for simple filtration, the soil should be porous, but not necessarily underdrained. The sewage is distributed over each portion of the ground intermittently, by means of branching carriers, which pass along ridges of soil about 20 ft. apart, or along contours of slopes, and are controlled by sluices. At intervals the sewage is turned into each carrier, and overflows down the slope. The sewage is screened before distribution, unless it has been subjected to preliminary filtration or precipitation. The effect is similar to that of simple intermittent downward filtration, of which, indeed, this is only a modification. The nitrates may, however, be reduced by vegetation.

The crops grown upon "sewage-farms" are very heavy. Italian rye-grass is well adapted for the purpose, since it grows rapidly and absorbs much sewage, but many other forms of vegetation can be substituted. If the land is limited in area, provision may be made for temporary excess of sewage after heavy rainfall by setting aside a portion of the ground as a land-filter.

It is usual, in cases where the approval of the L.G.B. is required, to provide at least an acre of land for each 300 of population if broad irrigation is adopted; or an acre for each 1,000 if there be either broad irrigation coupled with precipitation or intermittent downward filtration through underdrained land; or an acre for each 2,000 if precipitation is followed by land filtration. It is considered necessary to secure land to the above extent, even if artificial filters are provided.

Apart from the action of vegetation, the purifying effect of different soils shows considerable variation. The Rivers Pollution Commissioners found that a cubic yard of chalk or sand effectually purified 5·6 gallons of sewage per diem, applied intermittently; while a sample of loam purified 9·9 gallons under the same conditions. Peat had slight purifying power at first, but improved with repeated use, owing, perhaps, to increase in the nitrifying organisms. Intermittent filtration through suitable soil removed 70 per cent. of the organic nitrogen, and upwards of 80 per cent. of the organic carbon. On the whole it may be said that peat and stiff clay lands are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of top soil is very small, say 6 in. or less, the area of such lands which would be required for efficient purification would in certain cases be so great as to render land treatment impracticable.

The first Sewage Commission (1857-65) reported that "the right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided."

A further Commission (1868-74), appointed to inquire into the best means of preventing the pollution of rivers, reported with regard to chemical precipitation, intermittent filtration, and broad irrigation: (1) All these are to a great extent successful in removing polluting organic matter in suspension, but intermittent filtration is best, broad irrigation ranks next, and the chemical precipitation processes are less efficient. (2) For removing organic matters in solution the processes of downward intermittent filtration and broad irrigation are greatly superior to upward filtration and chemical processes.

Another Commission (1882-4), appointed to inquire into the system under which London sewage was discharged into the Thames, whether any evil effects resulted therefrom, and, if so, what remedial or preventive measures could be applied, found that evils did exist "imperatively demanding a prompt remedy," and that by chemical precipitation a certain part of the organic matter of the sewage would be removed. They reported, however, "that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a permanent measure. It would require further purification, and this, according to the present state of knowledge, can only be done effectually by its application to the land."

Experience has shown that with careful management a properly constructed sewage-farm can be carried on without nuisance or injury to the health of the surrounding population; but if the land becomes waterlogged from accident, defect, or inattention, grave nuisance may readily result. It was at first feared that parasitic and other diseases in animals and man would be promoted by the use of the produce of sewage-farms as food, but no such result has been observed.

Bacterial treatment.— Biological methods of sewage purification have of late been more thoroughly studied, with important results. They are dependent on aerobic and anaerobic organisms present in the sewage itself. (*See* p. 175.) The oxidation effected by the aerobic organisms has been increased by supplying oxygen more freely by artificial means on a *contact bed*, that is, a specially prepared filter charged intermittently with sewage which is allowed to rest for a time upon it; and the rôle of the anaerobes has been encouraged by previously subjecting the sewage to anaerobic fermentation, the effect of which is to bring about more complete solution of the organic matter and render it readily oxidizable. For this purpose the "septic tank" has become widely used. Thus, speaking broadly, two main systems have arisen: (1) an *aerobic* or contact-bed method, and (2) an *anaerobic* or septic-tank method.

The combined process depends upon two groups of organisms, namely, those that are able to break down and liquefy solid organic matter, and those that deal with it when in solution; but no strict line of demarcation can be drawn between them. (*See* p. 175.) Different systems depend upon anaerobic action, aerobic, or a mixture of the two. Whatever system is used, the two great agencies of breaking down and oxidation must be allowed ample opportunity. The two types are illustrated in Cameron's *septic tank* (anaerobic) at Exeter and many other places, and in the *multiple contact bacteria-beds* (aerobic) at the Davyhulme Works, Manchester.

Scott-Moncrieff passes sewage, after anaerobic treatment, through a vertical series of shallow coke filter-boxes, with intervening air-spaces; and finds that there is a differentiation of the microbes in the successive stages, so that if the sequence of the filters is changed the purification is for a time arrested, and the effluent becomes foul. Ducat's tank is filled with porous material, such as burnt ballast—finer below and coarser above; it is ventilated by field-pipes passing through at various levels, and the walls of the tank are for the most part built of open drain-pipes, placed transversely so as to admit air freely; it is claimed that the tank can be used continuously without rest, and that no further treatment is necessary. Automatic tipping troughs are used, by which the sewage drips on to the bed and is thus aerated. Dibdin employs a tank filled with coarse burnt ballast; the sewage is run in and allowed to stand for two hours, after which it is slowly run off—to filters, or to a second tank with finer materials—and the tank is allowed several hours' rest for aeration. Many new forms of apparatus are invented from time to time.

For contact beds which act partly mechanically as strainers and partly biologically, burnt clay, coke, clinker, cinders, or various forms of gravel may all be efficient media, provided there is ample aeration and porosity; loose-jointed tile drain-pipes are laid along the bottom to carry off the effluent. The depth of the beds may vary from 2 to 6 ft., and half an acre of bed is required for every 1,000–1,500 population. To assist in maintaining aeration the surface should be raked over from time to time. Obstruction by frost rarely occurs, the temperature of the sewage being from December to April about 55·5° F. Frequent and prolonged periods of rest are necessary; without them the beds become clogged, and eventually inactive because lacking in aerobic bacteria. The sewage applied to the bed should be as far as possible uniform in consistence and freed from suspended matters by sedimentation or screening. Mechanical sprinklers, dripping trays, or tipping troughs are used for the uniform distribution of the sewage on the bed.

The bacterial process is best conducted in three stages—(*a*) *settlement and screening out* of the grosser solids; (*b*) anaerobic decomposition in the *septic tank;* and (*c*) oxidation on bacteria *contact beds.* Fowler summarizes the conditions of the successful working of contact beds as the result of the Manchester experience as follows:—

(1) The bed should be worked very slowly at first, in order to allow it to settle down and the bacterial growths to form. In this way there will be less danger of suspended matter finding its way into the body of the bed, while the material is still loose and open. (2) The burden should not be increased till analysis reveals the presence of surplus oxygen, either dissolved or in the form of nitrates in the effluent. (3) Analyses of the air in the bed may usefully be made from time to time during resting periods. (4) The variations in capacity should be carefully recorded. If the capacity is found to be rapidly decreasing, a period of rest should be allowed. (5) Long periods of rest should be avoided during winter, as when deprived of the heat of the sewage the activity of the organisms decreases. If necessary, the burden on the bed should then be decreased by reducing the number of fillings per day, rather than by giving a long rest at one time. (6) The insoluble suspended matter should be retained on the surface by covering the latter with a layer of finer material not more than 3 in. in depth. The suspended matter thus arrested should not be raked into the bed, but when its amount becomes excessive it should be scraped off. This should be done if possible in dry, warm weather, after the bed has rested some days. By placing the inlet and outlet penstocks as close together as possible, the suspended matter will tend to concentrate in their vicinity, and its removal will be facilitated.

The Royal Commission on Sewage Disposal (Fifth Report, 1908) reported somewhat unfavourably on the septic-tank method used by itself, and declared that its chief advantages were settlement of suspended matter, digestion of some of the sludge, and equalization of strength of sewage.

It should be noted that if sewage contains pathogenic bacteria, and is then treated by bacterial methods, the effluent cannot certainly be assumed to be safer in this respect than the raw sewage diluted, and, therefore, effluents should not be passed into drinking-water streams, but on to the land.

Selection of method.—The choice among the various methods of purification of sewage must be determined largely by local considerations. We have already quoted the findings of the Sewage Commission of 1868 (*see* p. 323). If the sewage is fre from manufacturing effluents of injurious character and if a sufficient area of suitable land can be obtaine in a convenient position at a reasonable cost, *broa irrigation* is entitled to preference as the most rationa and economical method of treatment. If there i serious difficulty in obtaining suitable land, simple *intermittent downward filtration*, or the *bacterial treatment*, may be preferable; and *precipitation processes* and artificial filters for still smaller areas may suffice. The Royal Commission (1908) found that the average purification secured on sewage-farms was 78 per cent., and on contact beds 93 per cent. The effluents are much the same chemically. The Commission (1909) also showed that in practice no sewage has been found (whether containing pot-ale or other trade effluent) which cannot be purified by bacterial treatment.

Proper construction in the first instance, and careful management afterwards, are essential in every process, and without them nuisance cannot fail to result. It is desirable, for the sake of economy and of efficiency in management and supervision, that sewage should be dealt with at as few points as possible. The process of purification is greatly facilitated by the "separate" system of drainage, the volume of sewage being thereby reduced and rendered more constant.

In manufacturing districts the principal difficulty arises in connexion with trade effluents. Many kinds of manufacturing refuse if admitted into the sewers interfere with the efficacy of land filtration, either by clogging the soil or by chemically checking the process of oxidation. The latter condition also operates prejudicially in bacterial methods. In such cases a preliminary purification by precipitation is necessary, and it is probable that the effluents of different trades will be found to require different chemical treatment. If they are poured into streams without purification, they cause pollution exceeding in intensity that caused by domestic sewage. For each manufacturer in such a district to deal with his own refuse would entail a very heavy aggregate expense; and the multiplication of such works is in itself undesirable, since it must increase the risks of mismanagement and failure. Still, where trade effluents cannot be received into the sewers, the responsibility for their purification rests with those who produce them. In some cases the difficulty may be overcome by combination among manufacturers, and in others by the provision of a special intercepting sewer. A satisfactory compromise has been reached in some towns by the manufacturers partially purifying the effluents before turning them into the sewers.

The Royal Commission on Sewage Disposal (1912) stated provisionally for the guidance of Local Authorities that an effluent which complies with the following conditions would be satisfactory and may be passed into a stream:—

(1) That it should not contain more than 3 parts per 100,000 of suspended matter.

(2) That after filtration through filter paper it should not absorb more than 0·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 24 hours, 1·0 part in 48 hours, and 1·5 parts in 5 days.

CHAPTER X

DISPOSAL OF THE DEAD

THE daily average of deaths in England and Wales is 1,400–1,500. The disposal of this enormous number of dead (many of whom have died of infectious diseases) in such manner as to avoid danger to the living is a sanitary problem which, like many others, has only received due attention within comparatively recent years. The horrible overcrowding of graveyards which prevailed in the early part of last century is now rarely met with, and is only possible in the older grounds which are not subject to modern regulations, and which have not been formally closed by Order in Council. Seymour Haden has shown that if carcasses are covered by a foot of suitable earth, the perishable parts disappear inoffensively within twelve months, and, speaking broadly, it may be said that for every foot of depth below the surface of the soil one year or thereabouts is necessary for resolution. The present practice, however, and even the law, are inconsistent with burial sufficiently shallow to permit of the due action of the nitrifying organisms found only in the upper layers of the soil. The objects of earth-burial are further frustrated by the still prevalent use of metallic or heavy wooden coffins.

Burial-grounds.—The objects to be aimed at are rapid resolution and complete oxidation or absorption of the products. Hence the soil should be light, open, porous, and either naturally or artificially drained to a depth of not less than 8 ft., so that air and moisture may pass freely but in a finely divided state. Loam or sandy mould is about the best soil; clay is difficult to drain, retards decomposition by excluding air and moisture, and either retains the products of decomposition or allows them to escape through fissures. A loose stony soil allows gases to escape too freely. In cases of difficulty, as regards soil or drainage, the level may be raised artificially. It is desirable that burial-grounds should not closely adjoin dwellings.* While convenient of access, they should, therefore, be placed outside the limits of present or probable future dense building, and a margin of 20 ft. or more in width should be reserved for walks and planting. The surface should be grassed. Cemeteries should not be placed on elevated ground whence the natural drainage may find its way to dwellings below, or may contaminate any water supply. For obvious reasons, lands liable to floods or encroachment by streams or by the sea are unsuitable. (For Model Bye-laws *see* p. 725.) The ordinary grave space being 9 by 4 ft., it is usually estimated that an acre of ground is a minimum allowance for a population of 1,000 persons for 60 years. The four chief sanitary considerations, therefore, to be held in view in the provision of burial-grounds are (*a*) suitable soil and proper elevation of site, (*b*) a suitable position, especially with respect to houses and sources of water supply, (*c*) sufficient space, and (*d*) proper regulation and management. (**L.G.B.** *Memorandum*, 1908.)

There can be no question of the injurious effects of overcrowded burial-grounds upon the health of the immediately surrounding population, but there is no clear evidence of harm accruing under the conditions enforced in modern well-regulated cemeteries. The dangers to be apprehended are contamination of air and water, to which, perhaps, ought to be added the possible retention or even multiplication of the germs of specific disease, many varieties of which can live in the soil. Effluvia may rise to the surface, or pass laterally for unknown distances, possibly to the basements of houses; but this is not likely to happen if the conditions already specified are observed. The drainage, artificial or natural, must be so arranged that it cannot find access to any supply of drinking-water, be it stream, well, or other source. Investigations by Buchanan Young show that organic matter and bacteria are increased in the deeper layers of soil, but not in the upper reaches. In vaults and over graves with an insufficient covering of earth, fetid organic matter, ammonia, ammonium sulphide, and sulphuretted hydrogen have been found.

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* The Public Health (Interments) Act, 1879, prohibited the construction of a cemetery within 200 yards (reduced to 100 by the Burials Act, 1906) of any dwelling without the consent of the owner and occupier. There is no restriction if such consent is obtained, nor any prohibition of future building nearer to the cemetery.

Persons taking part in exhumations have in many instances suffered from febrile attacks of varying character and intensity; but as a rule nothing more than diarrhœa, and occasionally vomiting, results from such exposure, and that only in a minority of cases. Much depends upon the completeness of the putrefactive changes. Grave-diggers do not appear to be an unhealthy or short-lived class.

Brick graves, vaults, catacombs, heavy oak coffins, and (worst of all) lead coffins are all objectionable, and represent a futile attempt to prevent decomposition. They only retard the process, and render it far more likely to injure the living than if the pent-up gases and fluids were exposed to the deodorizing and oxidizing influence of aerated earth. Perishable coffins of wicker, light wood, or papier mâché are most suitable of all.

"The degree to which the purity of neighbouring wells is endangered by a burial-ground, and the distance to which contamination may extend, will depend in each particular case upon the relative elevation of the respective sites of burial-ground and well, and upon the nature and dip of the intervening strata and the direction and amount of flow of underground water, so that it is impossible to lay down a general rule for all cases. Fissured rock might allow foul matters to traverse considerable distances, while the interposition of a bed of clay or a water-tight fault would shut them off, or the passage through an aerated stratum of finely divided earth would oxidize and destroy them on their way. The risk of pollution would seem to be greatest when graves and wells are sunk near together in a shallow, superficial water-bearing stratum of loosely porous nature resting on impervious clay, the water in the superjacent bed being stagnant.

"It does not appear, however, that the risk to which wells are exposed from the proximity of a properly managed burial-ground is in ordinary cases great. It is probably less than that to which in unsewered villages they are exposed by soakage into the subsoil from cesspools and privies; seeing that the solid and liquid excretions voided by a human being in the course of a single year amount to several times the weight of his body.

"In this connexion attention may be called to the researches of Dr. Klein, the results of which are thus summarized (*Ann. Rep.*, L.G.B., 1899) by him:—'Direct experiment lends no confirmation to the general and popular belief that the microbes of infectious disease retain their vitality and power of mischief within dead and buried bodies for indefinite periods. On the contrary, these researches show that, as far as the bodies of the guineapig are concerned, the vitality and infective power of those microbes that have been made the subject of experiment passes away in a comparatively short time; that in most cases a month is sufficient for this result—that is to say, long before the coffins containing the buried bodies have shown any indication of leakage.' This statement, however, does not apply to poisonous chemical products of decomposition, which may long retain noxious properties, especially where the circumstances are such as to exclude free access of air.

"The precautions to be taken to avoid pollution of wells and springs in the neighbourhood of a burial-ground will depend much upon local circumstances; they may be said to be—1st, the intervention of a sufficient space between the burial-ground and the water source; 2nd, proper drainage, where necessary, in order that the subsoil water of the burial-ground shall be conveyed away; and 3rd, proper management of the burial-ground, so that the amount of organic matter in one place shall not be more than the soil can dispose of. In cases where the Board's sanction or approval is required, a site would not be approved if it appeared likely that the purity of existing water supplies would be endangered, though, as in the case of the erection of new houses when a burial-ground has come into existence, there is no power to prevent anyone from sinking a well on his own property, as near to the burial-ground as he pleases. Of course, should the well become polluted, it can be dealt with under the provisions of the Public Health Act. The reservation, free from interments, of a strip of land next the boundary, as before recommended, would be of service in this relation also.

"The drainage water from a burial-ground should not be allowed to enter a stream from which water is drawn for domestic purposes. Special treatment will be necessary of the subsoil drainage of a burial-ground before its admission to any stream in cases where the soil of the burial-ground is of unsuitable character so that the drainings from the graves will be liable to escape adequate filtration."—(L.G.B. *Memorandum*, 1908.)

Both urban and rural authorities are enabled by the P.H. (Interments) Act of 1879 to provide cemeteries for their districts, and must do so if required by the **L.G.B.** The cemetery need not be within the district of the **S.A.** It is incumbent to take action in this matter—

1. Where, in any burial-ground that remains in use, there is not proper space for burial, and no other suitable burial-ground has been provided.

2. Where the continuance in use of any burial-ground (notwithstanding there may be such space) is, by reason of its situation in relation to the water supply of the locality, or by reason of any circumstances whatsoever, injurious to the public health.

3. Where, for the protection of the public health, it is expedient to discontinue burials in a particular town, village, or place, or within certain limits.

4. Where, from unsuitability of the site or of the subsoil, or from inconvenience of access from populous

parts of the district, it is necessary to provide additional burial-ground accommodation.

If it is desirable, on the above or other grounds, to close any existing burial-place, a representation must be made to the Home Secretary for the purpose of obtaining an Order in Council to that effect, under the provisions of the Burial Acts, 1853–1906.

"The period for which cemetery provision on the above scale will remain available will be still further lengthened if the soil be of a sort to promote speedy decay of the coffins and bodies.* The length of time necessary to effect complete decomposition varies (the material of coffins being similar)* according to the nature of the soil, being shorter in a porous, well-aerated soil than in one which is either dense and clayey, waterlogged, or surcharged with animal matter. The bodies of children decay more rapidly than those of adults, under like circumstances. In an open soil, if an adult body be buried in an ordinary wooden coffin, at the end, say, of fourteen years the coffin and the softer parts of the corpse may be found completely decayed, only the larger bones remaining, and the coffin collapsed, so as to occupy a vertical space only a few inches in thickness; the grave might then, so far as sanitary considerations are concerned, be reopened nearly to its original depth, without disturbing the remains of the body previously interred. Thus, if the grave be made originally, say, 8 ft. deep, a number of burials may be made in it before it becomes so full of bones as to be unfit for further use. In a dense clay soil, on the other hand, such coffins are found intact after having been buried thirty years or more, so that in a grave 8 ft. deep in such a soil there would not be room for more than three adult interments, if the rules to leave at least 6 in. of earth between any two coffins in the same grave and not to bury within 3 ft. of the surface were observed.

* In ordinary circumstances, as pointed out on p. 331, burial in the earth in coffins of a perishable nature is to be preferred, on sanitary as well as on economic grounds, to the use of graves and coffins of durable and impervious materials. In the former case, if the earth is of suitable nature, the resolution of the constituents of the body into innocuous inorganic substances proceeds rapidly and uninterruptedly. In the latter case the poisonous products of a partial and arrested decomposition are sealed up—it may be to be liberated by the disturbance of the grave on a future occasion. But, as it is doubtful whether public sentiment is yet ripe for the prohibition of vault burial, provisions for its regulation have been inserted in the Model Bye-laws as to cemeteries with a view to reducing the dangers of this mode of burial to a minimum.

"Under the most favourable circumstances, if the population be stationary, and the soil of the burial-ground be of an open texture and of such a nature as to permit burials to the depth of 8 ft., it may be estimated that at least a quarter of an acre of ground should be provided for each thousand inhabitants to serve for a period of thirty years. More space will, of course, be needed if the population is an increasing one, or if the number of burials is increased by special circumstances, such as deaths in institutions, or bodies cast up from the sea. In wealthy districts, in which many family graves are likely to be purchased, the burial-ground will not—other things being equal—be available so long as in a poor district, in which most of the burials are in common graves; much of the ground in the first case being appropriated though not filled. In a poor district, on the other hand, the death-rate is likely to be the higher. Bodies buried in walled graves occupy the ground permanently, and do not by their decay make room for others."—(L.G.B. *Memorandum*, 1908.)

In excavations for new buildings in cities, not infrequently skeletons and coffins are met with, which it is necessary to remove. For removal from one consecrated ground to another a faculty from the bishop of the diocese may suffice, but otherwise application must be made to the Home Secretary, from whom "a licence for the removal of human remains," under the Burial Act, 1857 (s. 25), may be obtained. The remains are then suitably re-coffined in boxes and re-interred in a burial-ground where burials may legally take place.

Interments underneath or within the walls of any church built after 1848 are forbidden by the P.H. Act of 1848 (s. 83; re-enacted by the P.H. Act, 1875). No buildings must be erected upon any disused burial-ground, except for the purpose of enlarging a place of worship (Disused Burial Grounds Act, 1884).

Cremation.—In a crematorium of modern construction a body of average weight is reduced to about 3 lb. of inorganic ash within two hours. The usual fuel is coal and coke, but Fradet recommends gas. In either case, a ventilating shaft with pilot fire at its base is necessary. The chief objections to cremation are that the soil is deprived of the organic matter that would otherwise be returned to it, that it involves an unnecessary waste of the world's limited stock of combined nitrogen, and that the impossibility of exhumation would increase the facilities for concealing homicide. The first objection has no great weight at present, since little attempt is made to utilize burial-grounds by cultivation. The last is, however, more serious, and cannot be regarded as satisfactorily met by the proposition of minute and detailed autopsy in every case. Half a million examinations annually, each sufficiently detailed to cover every known poison and every possible wound, would be impracticable, especially as the result must, in the vast majority of cases, be negative. The discovery of organic disease would not by any means necessarily exclude the possibility of foul play. Some few poisons, such as copper, might be detected in the ashes, but organic and volatile mineral poisons would be dissipated by cremation. It is true that under present conditions occasion for exhumation rarely arises, but the possibility of it may to some extent act as a check upon crime. The Cremation Act, 1902, empowers Burial Authorities (Burial Boards or other local Authorities maintaining cemeteries) to provide and maintain crematoria. The plans and site must be approved by the **L.G.B.**, and the completion must be notified to the Home Secretary before any cremation takes place. No crematorium may be built within 50 yards of any public highway, within 200 yards of a dwelling-house (except by consent of owner), or within the consecrated part of a burial-ground.

Home Office Regulations of 1903 impose conditions as to maintenance, inspection (by Home Office and L.G.B.), disposal of ashes, and the further points stated below. Cremation is not allowed if the deceased has left written directions to the contrary, or if the body has not been identified. There must be (*a*) medical certificates as to the cause of death from two registered practitioners (one being the medical attendant and the other a practitioner of at least five years' standing who (1) is specially appointed by the Authority for the purpose, or (2) is **M.O.H.**, Certifying Surgeon under the Factory Act, or Medical Referee under the Workmen's Compensation Act, or (3) is physician or surgeon to a public general hospital with at least 50 beds; or (*b*) a certificate given after post-mortem examination by a skilled pathologist, or (*c*) a certificate given by a coroner after inquest. In certain circumstances (*b*) and (*c*) become essential.

A Medical Referee must be appointed by the Authority, and a deputy to act for him in his absence or in cases where he is the medical attendant. His certificate that all the conditions have been fulfilled is necessary before any cremation can take place, but certain relaxation can be allowed by him in exceptional cases (persons dying of plague, yellow fever, or cholera, on ship or in an isolation hospital; still-born children; bodies exhumed after burial for more than a year). Other modifications can be made temporarily by Order of the Home Secretary on application of the **S.A.**, during an epidemic or for other sufficient reason.

CHAPTER XI

ANIMAL PARASITES

IN addition to the pathogenic bacteria, belonging rather to the vegetable than the animal kingdom, the human body is liable to invasion by a number of parasitic animal organisms, among which the following are the most important.

Protozoa are unicellular animals, little more highly developed than some of the bacteria. They are usually divided into four classes: Rhizopods, Sporozoa, Flagellates, and Infusoria. The last-named group, which includes *Paramœcium*, need not be further considered. It is only recently that the relation between these protozoa and human disease has been demonstrated with any clearness.

The Rhizopods are the lowest group, and comprise the amœbæ which move by pseudopodia and reproduce themselves by simple division. Many kinds of amœba occur in the human intestine, some being genuine rhizopods in the vegetative stage, others being amœboid stages of higher forms. Two of the forms (*Gymnamœbæ*) are human parasites, namely, the *Amœba coli* (or, as it is termed by Schaudinn, *Entamœba*) and the *Amœba dysenteriæ* (*Entamœba tetragena* or *E. histolytica*). The former appears in the excreta of 20–50 per cent. of healthy persons, though it is not easy of detection. The latter (Fig. 47) is probably the cause, wholly or partly, of the amœbic type of dysentery, as commonly occurring in the tropics.

The Sporozoa are so called because at one stage of their life-history the individual breaks up into a number of minute reproductive bodies resembling the spores of fungi, often encysted. This group includes the *Gregarines* which inhabit the digestive tract of crustaceans, the *Coccidia* which are intestinal parasites in birds and in animals, and the *Hæmoprotozoa*, or parasites of blood corpuscles, classified by Sambon into four groups. The life-history comprises alternation of generations and change of host. Once the sexually-produced reproductive body or spore finds its way into a suitable host it attains its full size and then splits up into individuals which carry on the cycle.

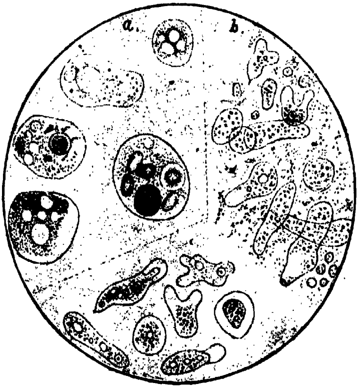

Fig. 47.—*a*, Amœba dysenteriæ, fixed and stained (*Councilman*); *b*, A. dysenteriæ in stools. (*After Lösch, Virchow's Archiv.*, *Bd. lxv.*)

Coccidium oviforme produces coccidiosis or psorospermosis in rabbits and other animals. *Pyrosoma bigeminum*, the cause of Texas fever in cattle, which is transmitted by a tick, is a closely allied organism.

The Flagellates include the *Trypanosoma* and *Trypanoplasma* genera. The latter occur in fishes only. The former cause various diseases of mammals, birds, reptiles, fishes, etc. They have now been shown to be the cause of certain diseases of man, such as trypanosomiasis, of which the terminal phase is sleeping sickness (Fig. 48), and some are conveyed by a fly, *Glossina palpalis* (p. 523). A trypanosome has a long spermatozoon-like body fringed on one side with an undulating membrane prolonged at the anterior end into a flagellum. The body possesses a large nucleus and a chromatine blepharoplast. The organism passes through various stages in its life-cycle, and a connexion has recently been established between the malaria parasite and the trypanosome. The majority of trypanosomes and other hæmoprotozoa have a life-

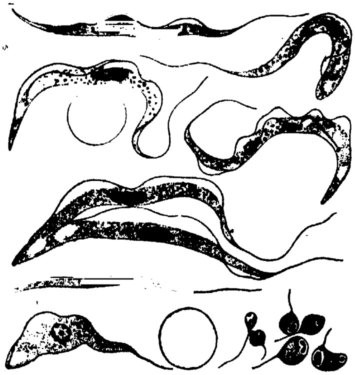

Fig. 48.—Various forms of Trypanosoma gambiense (the parasite of trypanosomiasis) from the blood and cerebro-spinal fluid.

cycle consisting of alternating gut-parasitism and blood-parasitism.

The next group of animal parasites infesting man are the Insecta and the Arachnida. Among the former are fleas, bugs, lice, the Pulicidæ, and the larvæ of certain flies; among the latter are the mites, ticks and *Pentastomata*. More important are the parasitic worms, which may be divided broadly into two groups as follows:—

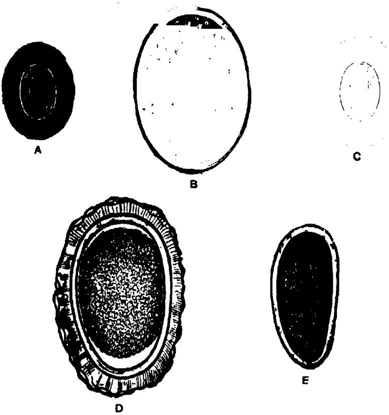

Fig. 49.—Ova of entozoa. × 350. (*Hillier.*)

A, Tænia solium; B, Bothriocephalus latus; C, Tænia mediocanellata; D, Ascaris lumbricoides; E, Oxyuris vermicularis.

1 The flat worms (Platyhelminthes), which are usually subdivided into the Cestoda or tapeworms and the Trematoda or flukes.

2. The round- or threadworms (Nemathelminthes) or Nematoda. This group includes the common thread-

worm (*Oxyuris vermicularis*), the common roundworm (*Ascaris lumbricoides*), and the various forms of filariæ and ankylostoma.

Tæniada.—It has been said that as many as a dozen forms of tapeworm occur in man. This species of Cestoda passes through two distinct phases, in two different hosts. In one, the head, or *scolex*, together with a cystic expansion, is embedded in muscle and other solid tissues; in the other, the *strobilus* or tapeworm occupies the alimentary canal of some other animal. If the flesh containing tænia cysts (*cysticerci*) is eaten by another animal, the scolex reaches the alimentary canal of the new host, loses its cyst, and attaches itself to the wall of the intestine. It then develops from the caudal end joint after joint of *proglottides*, square or oblong flat segments, each of which is provided with double sexual organs. The chain of proglottides may attain a length of many feet. Ova are produced in the segments, and escape with the excreta of the host if the segments rupture or become detached, or if the whole of the tapeworm is expelled. Some of the ova are swallowed by an herbivorous host, and the embryo then bursts its shell, makes its way from the intestine to the solid tissues of the host, and after developing anew into a cysticercus, remains passive until it is devoured by a carnivorous animal, or perishes.

Man is subject to tapeworms, and more rarely to their cysticerci. *Tænia solium*, one of the commonest of human tapeworms, attains a length of 7–10 ft. or more, consisting sometimes of 700 to 800 proglottides. The head is about the size of the head of a pin, and bears four suctorial discs, and a double circle of hooklets surrounding a prominence or *rostellum*. It attains its full development in three or four months, but may remain in the intestine for years.

The ovum (Fig. 49, A) is spherical, $\frac{1}{700}$ in. in diameter, and has a thick brown shell; the embryo has six hooks. The cysticercus or bladder worm of the *Tænia solium* is termed *Cysticercus cellulosæ.* It affects the pig, and more rarely man; in the latter it lodges in the muscles, connective tissues, brain, eye, and serous membranes, where it attains its full development in about two and a half months. The cyst reaches the size of a pea, or even a marble; the head or scolex has a double crown of hooklets. In pigs it constitutes the affection known as "measles," and the consumption of uncooked "measly pork" is the chief source of *Tænia solium* in man.

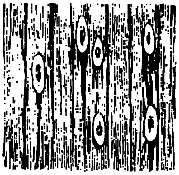

Fig. 50.—Cysticercus bovis in muscle. (*Leuckart.*)

Tænia mediocanellata is more common than *Tænia solium,* and somewhat resembles it, but its length is greater (20 ft.). The head is about $\frac{1}{15}$ in. in diameter, and has four suckers, but no rostellum or hooklets. The eggs (Fig. 49, c) are oval, the short diameter being about $\frac{1}{850}$ in. The *Cysticercus tæniæ mediocanellatæ,* or *Cysticercus bovis* (Fig. 50), is an oval vesicle smaller than the *Cysticercus cellulosæ.* It consists of a cyst, and a scolex identical with the head of the tænia itself. It occurs in the flesh of cattle and produces "beef measles."

Bothriocephalus latus. — This tænia attains a length of 24 ft. or more. The head is ovoid, $\frac{1}{10}$ in. long, and has two longitudinal grooves or suckers, but no hooklets. The body is ribbon-like and may have as many as 3,000 segments. The eggs (Fig. 49, B) are oval, about $\frac{1}{370}$ in. shorter diameter, and open by a lid at one end. The cysticercus is found in pike, turbot, perch, and other fish. It may, perhaps, gain access to the alimentary canal of the fish by means of water, as the embryo is ciliated and is found in river water. The tænia is met with principally in the Baltic countries (Russia, Poland, Sweden) and in Switzerland.

Tænia echinococcus (Fig. 51) affects the dog and wolf only. The head resembles that of *Tænia solium* in presenting a rostellum surrounded with a double row of hooklets and four suckers, but it is only $\frac{1}{100}$ in. in width. There are four segments only, and the whole adult tapeworm is about $\frac{1}{4}$ in. long. The eggs are spherical and contained only in the terminal or reproductive segment. Its cysticercus is a dangerous human parasite affecting the liver and various other parts of the body under the name of *hydatid*, which occurs more frequently in Iceland and Australia than in Great Britain. Unlike other cysticerci, it increases indefinitely in size, becoming sometimes a large cyst; it also forms within itself secondary cysts, some of which ("brood-capsules") contain one or more scoleces (*echinococci*) and remain minute, while others, containing no scolex, enlarge and form "daughter cysts," which may in turn produce new cysts by gemmation. After death the scolex or echinococcus resembles the head of the tænia, but during life it is retracted into a depression, and thereby turned inside out. Hydatids may continue to grow for an indefinite number of

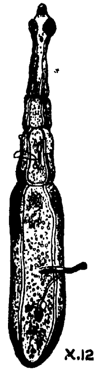

Fig. 51.—Tænia echinococcus. (*Leuckart.*)

years, and are spread among men and animals by affected dogs.

Tænia nana (Fig. 52) is occasionally met with in England. It is the smallest of the tapeworms inhabiting man, and, with half a dozen other types, is found commonly in tropical or subtropical countries.

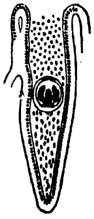

Fig. 52.—Tænia nana.

Trematoda or flukes furnish two human parasites, the *Bilharzia hæmatobia*, now termed *Schistosomum hæmatobium* (Fig. 53), and the *Distoma hepaticum.*

Bilharzia hæmatobia is believed to be the cause of a form of intermittent hæmaturia endemic in Egypt, South Africa, and elsewhere. The parasite is about ¼ in. long, and infests the veins of the large intestine, bladder, ureter, and pelvis of the kidney. It causes small patches of inflammation along these tracts, and the urine frequently contains blood and the ova of Bilharzia. The ureter may be obstructed. Dysenteric symptoms occasionally occur owing to the presence of the parasite in the veins of the intestine. The ova are about $\frac{1}{180}$ in. long, and have a sharp terminal spine, not quite in the longitudinal axis. The parasite probably gains access to the human body through water, either by drinking or by direct

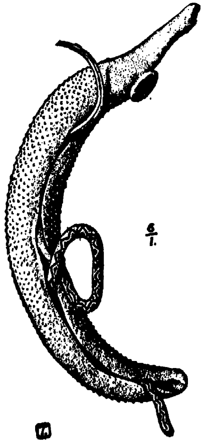

Fig. 53.—Schistosomum hæmatobium, male and female. (*Partly after Loos.*)

infection of the urinary and alimentary tract during bathing. The *larva* becomes encysted in the body of aquatic crustaceans. Other varieties of schistosomes occur.

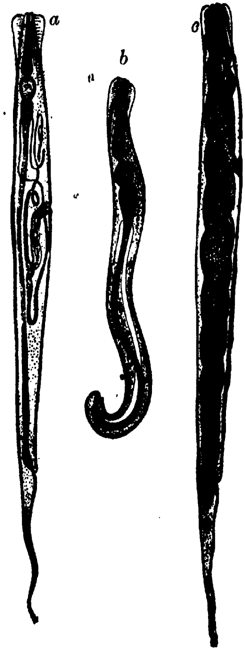

Fig. 54.—Oxyuris vermicularis. *a*, young female; *b*, male; *c*, mature female. (*Payne.*)

The common liver-fluke or *Distoma hepaticum*, which produces "liver-rot" in sheep, is shaped like a diminutive sole, and is about an inch in length. It may infect persons consuming affected livers, and may be found in the tissues, and particularly in the portal system.

Nematoda. — The common roundworm, or *Ascaris lumbricoides*, affects man and other animals. Its habitat in man is chiefly the small intestine. It is pinkish in colour, and tapers to each end. The male is about 6 in. long, the female 12 in. The eggs, enormous numbers of which are discharged, are oval and nodulated, and measure about $\frac{1}{450}$ in. in least diameter (Fig. 49, D). It is believed that the ova develop only in an intermediary host. The threadworm, *Oxyuris vermicularis* (Fig. 54), is smaller, the female measuring about half an inch in length, and the male about a quarter of an inch. They occur in enormous numbers, chiefly in the rectum. The ova (Fig. 49, E) are unsymmetrical but oval, their short diameter being $\frac{1}{1100}$ and long diameter $\frac{1}{500}$ in. The origin of threadworms is uncertain, but it is probable that they are occasionally disseminated by means of drinking-water.

The adult *Ankylostomum*, about half an inch long, inhabits the upper part of the jejunum in man, *A. duodenale* (Fig. 55) being found in Europe and the tropics, and *A. americanum* (or *Necator americanus*) in the United States and elsewhere.* It possesses no intermediate host, and there is no sexual generation outside the host. The infection of each host (man, sheep, etc.) is specific for each parasite. The adult alone is infective, the eggs and young larvæ being non-infective. The fresh ovum is characterized by a thin, clear, colourless shell of oval form, encasing greyish contents divided by segmentation, and eventually, on passing out of the intestine, becomes a *morula* before the emergence of an active vermiform embryo (in 18 hours). From the fresh egg the encapsuled larva appears in 2 or 5 days or longer. The second period of growth within the host from the encapsuled larva to the adult occupies about 5 to 7 weeks. The encapsuled larva is capable of saprophytic existence for many months under favourable conditions. The eggs are killed in about 24 hours at 40° C. or at zero, and below 13° C. they will not hatch. Moisture and free oxygen are necessary for development of ova after expulsion from the body.

Ankylostomum obtains access to man's intestine by the mouth or through the unbroken skin by way of

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* This nematode has also been termed *Sclerostoma duodenale*, *Dochmius duodenalis*, and *Strongylus duodenalis*.

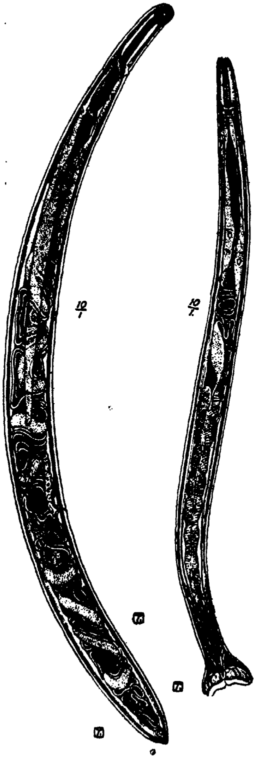

Fig. 55.—Ankylostomum duodenale, female and male. (*After Loos.*)

the hair-follicles as encapsuled larvæ (*Loos*). The latter is probably the most important path of infection and explains, in part, the skin irritability and eruption which precede invasion. From the skin it is carried by the blood-stream to the lungs, up the trachea, and down the œsophagus to the alimentary tract, in which the parasite attaches itself to the villi of the jejunum, abstracting blood and producing hæmorrhages. Ankylostoma can only obtain effective entrance to the human body in the stage of full-grown larvæ. Eggs are not infective. The duration of infectivity in man varies between 7 weeks and 6 years. The typical results of infection are erythema and urticaria of the skin, bronchial catarrh, and pain in the epigastrium, followed by anæmia, and sometimes associated with dyspeptic conditions. The anæmia is mainly due not to reduction of hæmoglobin but to increase of plasma. It is determined by individual susceptibility, and dose and frequency of infection. Many persons harbouring the worm suffer from no symptoms of disease at all. Dobson found eggs in the excreta of 75 per cent. of the natives of Assam; and Boycott found them in 95 per cent. of workers in certain Cornish mines, although not more than 5 per cent. of the men were actually ill. The healthy worm-carrier is probably one of the chief factors in dissemination, and may continue to discharge ova for years. The disease has long been known as "Egyptian chlorosis," tropical anæmia, or miners' anæmia, but has only recently been fully described by Haldane, as "Dolcoath anæmia." It was no doubt the cause of miners' anæmia in the St. Gothard Tunnel in 1880. It is now termed **ankylostomiasis**, and is recognized as an endemic disease of warm climates, readily introduced into temperate climates by dissemination of the worm, and very widely distributed. The effect of temperature operates, however, in cold climates. For instance, Tenholt has shown that in Westphalian mines where the temperature is below 17° C. the cases of ankylostomiasis (anæmia) per 1,000 men employed underground were only 0·6, whereas where the temperature was 20–22° C. they were 2·5, where it was 22–25° C., 11·7, and where above 25° C., 39·9 per 1,000. Treatment consists in purgation (calomel), followed by three successive doses of 30 grains of thymol. In Westphalia ethereal extract of male fern is used. Preventive measures are based upon personal precautions against ingestion or skin infection, and against the fæcal contamination of the soil and water. The separation of the diseased from healthy persons is necessary.

Trichina spiralis attacks rodents, pigs, and many other animals besides man, causing the disease known as **trichinosis.** It is found in the tissues, and especially in the muscles, in the form of ovoid cysts about $\frac{1}{70}$ in. in length, just visible to the naked eye. Within each cyst is coiled an immature trichina, about $\frac{1}{35}$ in. long. The encapsuled trichinæ may retain their vitality for many years, or may perish and become calcified. If the tissues in which they lodge are eaten, the capsule is dissolved by the gastric juice, and the liberated trichinæ rapidly develop, the male attaining in one or two days a length of $\frac{1}{18}$ in., the female $\frac{1}{8}$ in. Ova are formed and impregnated, and are hatched within the uterus in about a week. The embryos escape, burrow into the walls of the intestine, and find their way into the tissues of all parts of the body, where they become encapsuled and form the cysts already described, within a month from the ingestion of the trichinous food.

Trichinosis in man is generally due to the consumption of the imperfectly cooked flesh of a pig suffering from the disease. In countries where ham, pork, and sausage are eaten raw, trichinosis is of far more common occurrence than in England. The symptoms commence within a week, with nausea, abdominal pain, irregularity of the bowels, prostration, rapid pulse, and elevation of temperature. The malady usually increases in severity for one or two weeks, and then gradually subsides, but fatal enteritis, peritonitis, or pneumonia may supervene, or the patient may die of exhaustion at any time from the end of the first to the end of the sixth week. Characteristic symptoms attend the invasion of the tissues by the parasites. The muscles become painful, tender, swollen, and stiff, so that the limbs are flexed and motionless. The voice is often hoarse or aphonic, from implication of the larynx. The pain in the limbs differs from that of rheumatism in not affecting the joints, but only the muscles. Œdema occurs early, first in the eyelids and face, next in the hands and feet, and may become general and involve the serous cavities. The other symptoms include increasing prostration and copious perspiration.

Various forms of **Filaria** may infest man, particularly in the tropics, setting up filariasis, abscess, lymphangitis, chyluria, elephantiasis, etc. *F. bancrofti*, rarely seen in the adult form, is a hair-like parasite and may attain a length of 3 or 4 in. An immature form, met with in cases of chyluria, is about $\frac{1}{75}$ in. long. The ova are about $\frac{1}{1000}$ in. long, and, having no distinct shell, their shape is somewhat irregular. The parasite is found chiefly in the East and West Indies, but occasionally in England, even among persons who have never left the country. The mosquito is its intermediary host. It abounds in the blood of affected persons during the night (*Filaria nocturna*, Fig. 56), but disappears from the circulation by day; by changing the habits of the patient this "filarial periodicity" can be reversed. Its presence is commonly associated with one of two diseases—chyluria and elephantiasis—due to the obstruction of the lymphatics, etc., by the parasite. The former is characterized by periodic attacks, in which the urine becomes milky and upon standing coagulates, but the coagulum soon breaks down and decomposition sets in rapidly. These phenomena have been traced to admixture of lymph with urine, and immature *filariæ* are visible under the microscope. Elephantiasis is attended with enormous enlargement of the trunk or limbs, and especially the legs and generative organs (E. arabum).

Filaria medinensis vel dracunculus, or Guinea-worm, is about $\frac{1}{10}$ in. in diameter, and usually 1-3 ft. long. It is endemic in certain tropical regions. The embryos affect minute aquatic crustacea (Cyclops), in which they undergo larval development. Later they gain access to the human tissues (by drinking - water or infection through the skin). They burrow in the tissues, especially of the legs, causing large boils and sores.

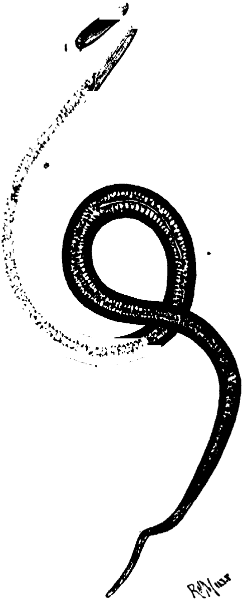
Fig. 56.—Filaria nocturna.

Parasites of the skin.—*Acarus scabiei hominis* (Fig. 57, A, B) produces a parasitical disease of the skin of the hands, wrists, feet, ankles, etc., known as **scabies.** The female acarus burrows in the skin and deposits her ova in the deep epidermis. She has eight legs, the anterior ones being suckers, the posterior ones bristles. The symptoms are itching, local irritation, inflammatory reaction, and eczematous eruption in various parts of the body. The treatment is aimed at destroying the burrows and the parasite and relieving subjective or secondary lesions. Hot air, soft soap, and sulphur ointment or vapour are used, and the clothes must be disinfected. *Demodex* *folliculorum*, a minute acarus, lives in sebaceous glands and forms "black-heads."

Pediculi (lice) are of three types—*P. corporis*, or

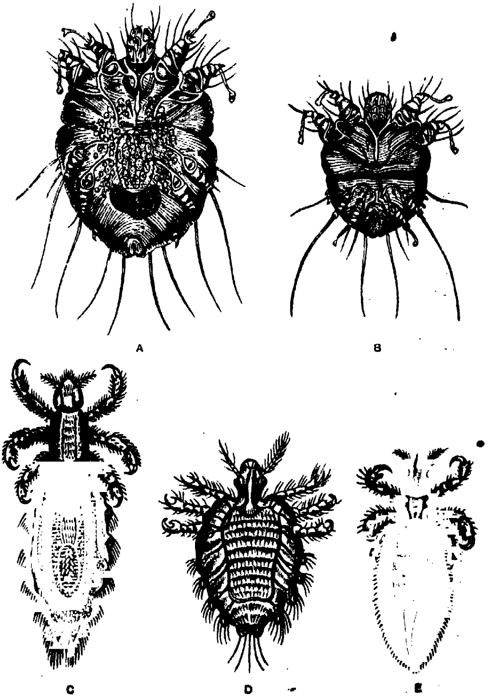

Fig. 57.—A, B, Female and male Acarus scabiei, × 100 (*Kaposi*). C, Pediculus corporis, × 50; D, P. pubis, × 35; E, P. capitis, × 35 (*Küchenmeister*).

body louse, *P. pubis*, or crab louse, and *P. capitis*, or head louse (Fig. 57, C, D, E). They are the exciting cause of **pediculosis.** The lice are blood-suckers, and the signs of their presence are their bodies and the

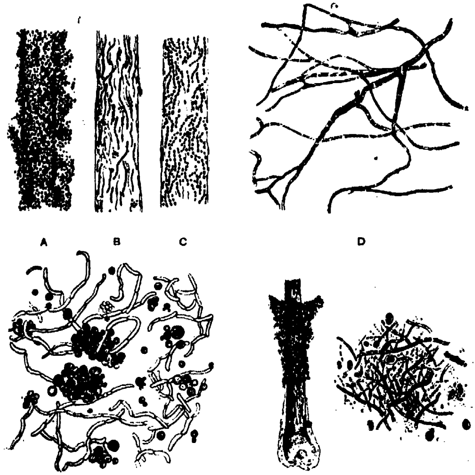

Fig. 58.—Tineæ and favus parasites.

A, ringworm (Microsporon audouini) in hair, surface view, with mosaic of spores, × 200; B, ringworm (Microsporon audouini) in hair, optical section, with mycelium, × 200; C, ringworm (Trichophyton) in hair, with spores arranged in chains ("rosary" arrangement), × 200; D, trichophyton mycelium, from a culture, × 250; E, Microsporon furfur spores in clusters, × 250; F, favus (Achorion schönleinii), showing affected hair, × 70; G, favus (Achorion schönleinii), showing fungus in a crust, × 290.

consequent irritation, minute hæmorrhages, excoriations, etc. There is sometimes pyrexia, and suppuration may follow. The lice are found most commonly on the clothing, folds of linen and inside of collar, The pediculus has an oval or triangular head and six legs. It is very prolific. Cleansing, insecticides (cresol, naphthalene, sassafras, etc.), and dry-heat disinfection of clothing constitute the treatment. The common flea (*Pulex irritans*) and the bug (*Acanthia lectularia* or *Cimex lectularius*) are often associated with pediculosis.

The parasites which cause **ringworm** may be noticed here, although they are not animal parasites. They belong to two genera of fungi, microsporon and trichophyton, the former being concerned in the special type of school-child ringworm. The types are differentiated by size of spores, and shape, arrangement, and mode of growth. The mycelium of the microsporons is irregularly jointed, curved, and branching; that of the trichophyton (Fig. 58, D) is short and regularly jointed. The microsporon lies around the hair as a sheath, eats its way into the shaft, and grows downwards to the root; the trichophyton attacks the root and grows upwards. In both infections the hair breaks off short. Tinea tonsurans is mostly due to *Microsporon audouini*, and Tinea circinata to trichophytons. Ringworm represents a destruction of the hair and an inflammatory process set up by irritation. This begins with a papule which grows into a patch that may become as large as a clerical tonsure (hence *tonsurans*). The patch is studded with dry, withered stumps of broken hairs, and black dots, follicles, scaliness, and baldness are prominent. Treatment consists of (*a*) epilation by X-rays or otherwise, (*b*) removal of superficial crusts, etc., (*c*) application of parasiticidal agents (iodine, carbolized glycerin, etc.). Tinea versicolor is produced by *Microsporon furfur* (Fig. 58, E), and favus by the *Achorion schönleinii* (Fig. 58, F, G), which fills the hair with its mycelium and causes yellow cup-shaped crusts. This latter condition is now rare in school-children in this country.

CHAPTER XII

INFECTION AND IMMUNITY

CERTAIN diseases, the number of which is steadily increasing owing to improved methods of observation, are termed specific or infective, and are regarded as due to the invasion of the system from without by a definite germ, "ferment" or poison, which grows and multiplies in the body. In some of these diseases the agent of infection is given off again, and such diseases are therefore infectious, or transmissible from person to person. For the production of an infective disease there must be (*a*) a specific germ or contagium of the disease, (*b*) a susceptibility to the infection (due to age, sex, predisposition, habit, environment, previous disease, fatigue, etc.) on the part of the individual, and (*c*) a means or channel by which the specific infection is conveyed.

Modes of infection.—It cannot be said that the possible means by which infection is given off have been exhaustively determined in regard to any disease, but certain well-established modes may be mentioned, namely :—

1. **Inoculation**, as in human vaccinia, rabies, syphilis, and some septic affections.

2. **Personal conveyance:** (*a*) By the *breath*, as in smallpox, measles, whooping-cough, pneumonia, mumps, typhus, scarlet fever, and probably in the great majority of infectious fevers. Little is known of the distance to which infection can be carried through the air; long ranges seem to be possible in smallpox, and may be suspected in measles and

whooping-cough; typhus and plague only infect at short distances, and this is probably true of scarlet fever. The distance of infection is short in ordinary breathing, but relatively long in shouting, coughing, sneezing, etc. Recent investigation has shown that particles of "cough-spray" may be carried 70 ft. (*Gordon*).

(*b*) By *exhalations*, from the skin in typhus and possibly other diseases, from wounds in pyæmia, erysipelas, and other septic diseases.

(*c*) By *desquamated particles* of epidermis in scarlet fever, and pustules in smallpox. These may be carried by currents of air.

(*d*) By *secretions* and *excretions.* Mucus from the mouth, throat, etc., is infective in diphtheria and scarlet fever; sputa in tubercular phthisis; saliva in rabies in dogs if not in man. The bowel excreta are infective in enteric fever and cholera, and possibly in diarrhœa. The urine is also a vehicle of infection in some acute specific fevers, as, for instance, in enteric fever. Syphilis and gonorrhœa are transmitted by means of the specific discharges.

(*e*) By *contact*, kissing, etc. Diphtheria, venereal disease, and purulent ophthalmia may be thus conveyed.

3. **Mediate infection**, on articles of clothing, is responsible for conveyance of secondary infection in hospital, in rag-sorting, etc.

4. **Food and drink.**—Milk, water, and bacterially infected foods.

5. The **bite of certain infected insects**, such as mosquitoes (malaria and yellow fever), fleas (plague), or the carriage of infection by **flies.**

Flies and disease.—The common housefly (*Musca domestica*), non-biting, occurs in all parts of the world. It breeds in heaps of fermenting material, especially horse-manure. The life-cycle from egg to maturity occupies 3-4 weeks. Flies can travel considerable distances and can deposit bacteria from the surfaces of their bodies and limbs, in fæcal material, and in vomit from the crop (*Graham Smith*). Some bacteria may continue to live in the dead body of the fly. In one or other of these ways flies may act as carriers of disease germs. They are a principal factor in the dissemination of typhoid fever in military camps and tropical stations; and in temperate climates they transmit epidemic diarrhœa, particularly in summer time. The annual diarrhœa epidemic in large cities seems to be correlated in time-incidence, extent, and degree with the weather conditions which influence the emergence, activities, and number of flies (*Niven*, *Robertson*, *Graham Smith*). They are attracted to tuberculous sputum, and can carry and distribute the tubercle bacillus contained in it for several days. Cholera, plague, yaws, anthrax, and infective ophthalmia may also be conveyed by flies. The larvæ of some species of non-biting flies cause *myiasis* in man (skin, subcutaneous tissue, neglected wounds, and alimentary canal). Whilst flies can be caught on papers or in traps. the only radical means of restricting them, and thus reducing risk of infection, is by removing or destroying their breeding-places. Blood-sucking or biting flies are now known to be the agents of infection in various tropical diseases. In 1877 Manson discovered that *Filaria bancrofti* developed within the *Culex* mosquito; in 1895 Bruce discovered his trypanosome in the tsetse-fly; and in 1897 Ross demonstrated the relation of the *proteosoma* to the mosquito. Biting flies are now known to act as agents in the conveyance of malaria, sleeping-sickness, yellow fever, and possibly dengue. The infection is direct and mechanical, or is indirect and involves cyclical development as in malaria.

As regards the recipient, the mode of infection is also varied. Many diseases are conveyed through the air, and the virus is doubtless inhaled, lodging either on the fauces or in the lungs. Water is known to be able to convey the poison of enteric fever and cholera, and milk that of scarlet fever, enteric fever, and diphtheria, the poison in such cases being swallowed. It is probable that the specific organisms multiply in these media. Experiments seem to show that the acid gastric juice kills microbes that are not in the spore stage, but, since the reaction is not acid in the absence of solid food, this safeguard is incomplete, especially as regards water-borne virus. Infective particles carried by materials, clothing, etc., or conveyed by the hand to the mouth, may be inhaled or swallowed. Flies may convey infection to a raw surface, or to milk or other food. An attempt is sometimes made to distinguish as "contagious" those diseases which are not usually transmitted without direct personal contact; but this condition is not absolute, though favourable to the transmission of any infectious malady. Puerperal fever may be regarded as an example of infection by contact or inoculation. A few diseases, of which rabies and vaccinia are typical examples, can only be conveyed by inoculation, that is, by lodgment of the virus in an abrasion of the skin; this is the ordinary mode of infection in anthrax and glanders, although inhalation is also possible. Smallpox, tuberculosis, syphilis, and certain other diseases are also inoculable. Inoculation may occasionally take place through unbroken skin. This has been shown to be possible as regards virulent cultures of the glanders bacillus if rubbed in. Ankylostomum is believed to gain access through the hair-follicles (p. 348).

In leprosy the mode of infection is still unknown, although the microbe has been isolated. Even less has been made out in regard to rheumatic fever, the specific nature of which, though probable, still remains open to doubt.

"De novo" hypothesis. — Some authorities believe that certain specific diseases occasionally arise *de novo*, independently of infection from any previous case. This has been alleged more especially as regards relapsing fever, typhus, enteric fever, diphtheria, erysipelas, puerperal fever, hospital gangrene, and septicæmia. The closest examination often fails to reveal any exposure to infection, and occasionally, under favourable conditions, these diseases spring up in localities that have for years been entirely free from them. The tendency of modern research, however, is to find an adequate explanation in infection conveyed by "carriers," by food, by insects, by air-borne micro-organisms, by lower animals suffering from the same disease, possibly with widely different manifestations, or by aberrant forms or unobserved attacks in man. The supposed logical necessity for a "previous case," that is, of an immediately antecedent *human* case, has lost some of its significance since we have learned to recognize the actual living agent or germ, to detect it in air, water, and soil, to cultivate it in artificial media for indefinite periods, to transmit it to lower animals, and to increase or lessen its virulence at will. It is noteworthy that most of the infective diseases suspected of origin *de novo* are filth-diseases, and due to microbes that can be cultivated outside the living body. Further, it has been found that there are non-pathogenic microbes of wide distribution, which in every point except virulence closely resemble the specific microbes of enteric fever and diphtheria; and non-pathogenic bacilli, morphologically similar to anthrax bacilli, have been found to be protective against anthrax. Some authorities regard these harmless microbes as being probably generically associated with the virulent microbes that they resemble, and therefore capable of assuming a virulent character if cultivated under suitable conditions—a view that re-introduces the *de novo* hypothesis in a new form.

Endemics, epidemics, pandemics.—Many of the specific diseases, and especially those that have relation to telluric conditions, attach themselves more or less permanently to certain localities, and are termed *endemic;* thus, cholera has been endemic in the delta of the Ganges, leprosy in parts of Norway, the plague in India and elsewhere, and in a less marked degree diphtheria, enteric, and scarlet fever may be said to have been endemic in certain districts in

England. From time to time most diseases of the specific class become widely prevalent over a larger or smaller area, and are said to be *epidemic.* Thus cholera in an epidemic form occasionally spreads westward over Europe, disappearing almost entirely in the intervals. Smallpox, scarlet fever, measles, and other diseases, which are always present in England, assume an epidemic form every few years, locally or in widespread outbreaks. Occasionally a disease diffuses itself so generally over a great part of the globe as to constitute a *pandemic.*

The causes of such outbursts are still imperfectly known. They have been attributed vaguely to "epidemic constitution" of the air, to "pandemic waves" of unknown nature, and, more intelligibly, to climatic and meteorological conditions, accumulation of susceptible persons or animals, increased virulence of infective agent, facilities for convection or transmission, and (as regards cholera and other filth-diseases) imperfect sanitation. Scarlet fever, in temperate climates where it has established itself permanently, tends to become epidemic at intervals of about five years; measles at intervals of about two years. Whooping-cough is more irregular than either, but on an average becomes prevalent every second year.* Diphtheria shows no very marked periodicity, apart from its dependence upon season, and enteric fever little or no regular periodicity.

It will be seen subsequently that the liability to each kind of infection varies in man according to age and sex, as well as locality, climate, season, and surroundings. Similar variation occurs among the different races of men, and still more conspicuously among the different genera and species constituting the animal kingdom.

Briefly, the occurrence of outbreaks is due to **three factors of epidemiology:** (*a*) an infective agent, the virulence and degree of infectivity of which is relatively high; (*b*) a large number of susceptible persons; and (*c*) a favourable association and environment. The infective agent may be imported or conveyed by various channels, including animals and insects. The relative susceptibility or immunity of the population is all-important. The environment includes various factors affecting the virus or the person infected, such as climate, temperature, soil, housing, aggregation of persons, schools, etc. The rise and fall of epidemics follow a recognized course, and depend upon a variability and persistency of type of infection as well as variations of susceptibility and environment.

The more important specific *diseases of animals communicable to man* are vaccinia, plague, tuberculosis, anthrax, rabies, tetanus, glanders, actinomycosis, and septicæmia. Influenza ought possibly to be added to the list. There is reason to believe that some form of diphtheria and scarlet fever may affect the cow. Variolous diseases attack sheep and other animals, but are probably not identical with smallpox.

Incubative period.—A latent or incubative period intervenes between infection and the appearance of the first symptoms of the disease. It is fairly constant for each disease; but shorter and more uniform when infection is due to inoculation or ingestion, and in rabies, naturally produced, is dependent further upon the position of the bite of the rabid animal.

Little is accurately known of the changes that occur during incubation, beyond the fact that the toxin is multiplying in some part of the system.* The onset of symptoms is usually gradual in enteric fever and a few others, but sudden in the majority. The temperature invariably rises, and the characteristic phenomena of each malady follow with more or less intensity. A rash makes its appearance upon the skin in certain of the infectious diseases, hence termed *exanthĕmata*; the date of its appearance is constant for each disease within narrow limits, and its distribution and other characteristics are also more or less uniform. The chief exanthemata affecting man are smallpox, varicella, scarlet fever, measles, rötheln, enteric fever, and typhus. In exceptional cases the rash, like any other given symptom, may be absent or modified.

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* Concurrence of two distinct zymotic diseases is occasionally observed. Vaccinia and smallpox, measles and whooping-cough, measles and scarlet fever, measles and mumps, whooping-cough and chickenpox, are among the least rare examples. According to Squire, diseases with similar incubation (i.e. both long or both short) may run their course independently without interfering with each other, but if two diseases with dissimilar incubation are acquired at the same time, one or the other is delayed.

Course of disease.—Infective diseases follow a definite course—*infection, incubation, invasion, determination*—ending in death, or in recovery with or without permanent changes in tissues and organs. Some, however, like syphilis and leprosy, run a lifelong course, while malarial diseases tend to recur at regular intervals, or after years of apparently complete recovery. Rabies and some other diseases are, as a rule, rapidly fatal, while rötheln, mumps, and varicella are attended with such slight constitutional disturbance that death is very rare. The tendency to death may be dependent upon constitutional symptoms such as hyperpyrexia, on local lesions as in enteric fever and diphtheria, on complications in the course of the disease (often really part of the disease itself), or, lastly, on sequelæ affecting important organs.

The intensity of any given disease is subject to wide variations. Thus, smallpox may be so virulent as to kill the patient before any rash appears, or so mild that only one or two spots, sometimes none, may appear. Scarlet fever sometimes is malignant and rapidly fatal, in other cases so slight as to escape recognition. As a rule, the type, whether severe or the reverse, holds good for the majority of attacks in a given outbreak, or at all events in the same period of the outbreak; but it is commonly more intense in the earlier than in the later part of an epidemic. As regards purely seasonal variations, however, there is reason to believe that in scarlet fever, and probably in other diseases also, increased prevalence is associated with diminished average severity, as measured by the proportion of deaths to attacks. Age and sex have an important influence upon severity of attack as well as upon susceptibility, varying with different diseases; thus scarlet fever, whooping-cough, and many other diseases become less and less dangerous to life from infancy upwards, while in enteric fever the reverse is the case. Both scarlet fever and smallpox are less liable to terminate fatally in females than in males, and the same seems to be true also of influenza.

The germ theory, broadly stated, affirms that certain specific diseases are invariably associated with the growth and multiplication in the system of corresponding specific microbes, and that these microbes are the primary causes of the disease. The evidence is partly direct, partly indirect.

1. In regard to a few diseases the proof is complete, since—(*a*) a specific microbe is invariably discovered in the blood or tissues of animals suffering from the disease in question; (*b*) this microbe can be cultivated in artificial culture media, for any required number of successive generations; (*c*) the same disease is reproduced by inoculation of a susceptible animal with the last cultivation; and (*d*) in every such inoculated animal the specific microbe is found, with the same distribution as in animals infected in the ordinary way.*

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* To these four postulates, formulated by Koch, Martin has added a fifth, namely, that the secondary infective agent (toxin) separable from the tissues in the natural disease should have similar chemical and physiological action to the products obtained from a pure cultivation of the microbe. Agglutination may prove to be a sixth postulate.

The third stage (c) being, as a rule, inadmissible as regards man, the complete proof is practically limited to diseases that attack some lower animal. Of those affecting man (as well as lower animals), anthrax and tuberculosis have been fully proved to be associated with specific microbes, and similar complete evidence is forthcoming in respect of many diseases attacking lower animals only.

2. A characteristic microbe is constantly found in the blood or tissues of persons suffering from certain other diseases—e.g. relapsing fever, enteric fever, diphtheria, leprosy, pneumonia, cholera, etc.—although the proof of causative relation is incomplete. In several diseases, however, which from analogy are nevertheless believed to be microbial, no specific or characteristic organism has been isolated with certainty. Measles and whooping-cough may serve as examples.

3. There is a close analogy between the natural history of infection and that of organized living ferments such as yeast, in respect of the almost infinite multiplication of an infinitesimal charge planted in a suitable soil under suitable conditions, and also in respect of the effect of reagents in checking or permanently arresting their increase.

The germ theory is now generally accepted, even in respect of those specific diseases, such as rabies, in which no characteristic microbe has yet been isolated. The chief alternative view which has been advocated is that infection is due to an unorganized chemical ferment, comparable to diastase, the microbes being regarded as (at most) effects or collateral phenomena without causative influence as regards disease.

What the precise relation between the germs and the production of the varied phenomena of disease may be is less clear. Under certain conditions the enormous multiplication of the microbes may lead to obstruction of vessels—a "mechanical mycosis"—but the ordinary course of symptoms cannot be accounted for by any mechanical effects of such minute particles. They act mainly by modifying the physiological processes of the tissues—e.g. by depriving the red corpuscles of oxygen, or by forming some chemical product (or toxin), as a result of their growth and multiplication, which in its turn diffuses and acts as a poison.

Bacteria and disease.—The terms microbe, micro-organism, bacterium, germ, are applied almost indifferently to an increasing number of these microscopic organisms. They are destitute of chlorophyll and consist of protoplasm enclosed in a cellulose membrane. They multiply by fission, and are therefore termed *Schizomycetes*, or *fission fungi*. The common basis of primary classification is founded upon morphology as follows—

Micrococci.—Minute spherical microbes, without cilia. They multiply by elongating and then dividing transversely, forming *diplococci* (i.e. pairs), *streptococci* (chains), *staphylococci* (clusters), *sarcinæ* (square groups of four cocci, or multiples of these), or *zooglœa* (irregular masses embedded in a gelatinous matrix).

Bacilli.—Rod-shaped, with rounded or square-cut ends; longer than they are broad. Some have flagella, others have not and are immotile. They elongate, and may form rods of any length, or divide transversely into separate short rods or chains of rods or zooglœa. Some bacilli form spores under certain conditions, among which may be mentioned moisture, suitable temperature, and presence of oxygen. The spores are round or oval glistening bodies, which appear in the substance of the bacillus, and grow at the expense of the protoplasm until the sheath bursts and liberates them. They are extremely resistant to heat and cold, but in certain culture media spores readily germinate, a projection appearing at one point and growing into a bacillus.

Spirilla, spirochætæ, and vibriones.—Long, wavy, and motile (ciliated) filaments. Some of these are non-septate, others are subdivided and may break into bacillary elements;

as, for example, Koch's spirillum of cholera, which is known in a bacillary form as the comma bacillus of cholera.

The higher bacteria include the more highly organized members of the Schizomycetes which branch and reproduce themselves by terminal fructification in Conidia. To this group belong leptothrix, cladothrix, and streptothrix. The last-named seems likely to become the most important member of the group from a pathogenic point of view. The exact biology of these higher bacteria has not been finally worked out, and it is possible that further research may show that sometimes they are but stages in the life-history of an organism appearing at some stage in bacillary form.

Micrococci are of constant occurrence, and pathogenic in septic processes, acute suppuration, acute infective osteomyelitis, cerebro-spinal meningitis, Mediterranean fever, and erysipelas. There is strong evidence of the same relation in pneumonia, gonorrhœa, ulcerative endocarditis, scarlet fever, and puerperal fever; micrococci are generally present in active lymph of vaccine and smallpox, and the virulence is largely or wholly lost when they are removed by filtration; but beyond this tho proof of their being the actual *materies morbi* is incomplete. Ammoniacal fermentation of urine is determined by *M. ureæ*, which converts urea into ammonium carbonate. Certain diseases of animals are believed to be due to specific micrococci, which are also concerned in decomposition.

Bacilli are known to be pathogenic in anthrax, tuberculosis, tetanus, glanders, plague, and leprosy, and are believed to be so in enteric fever, diphtheria, septicæmia, influenza, and various forms of food intoxication. Many diseases affecting lower animals are due to specific bacilli, and among them malignant œdema, swine fever, and *Rauschbrand* ("symptomatic anthrax" or "black leg"). The fermentation of cheese and butter, and the souring of milk and cream, are likewise due to bacilli. Each fermentation and most forms of decomposition possess a specific ferment of this nature.

Spirillum obermeieri is found in the blood during acute relapsing fever; the spirillum of cholera, or *Vibrio choleræ asiaticæ*, is regarded as the cause of cholera; *Spirochæta pallida* is associated with syphilis; and other forms occur in certain tropical diseases (yaws, etc.).

It should be mentioned that other micro-organisms, not classed with bacteria, have relation to disease and fermentative processes. Thus, thrush is due to *Oïdium albicans*, a mycelial form of a *torula* (*Saccharomyces mycoderma*). Mycelial growths, with spores or *conidia*, are associated with ringworm (*Microspora* and *Trichophyta*), favus (*Achorion schönleinii*) and pityriasis versicolor (*Microsporon furfur*). (*See* p. 355.)

Actinomycosis is characterized by the presence of a mycelial growth, with masses of club-shaped corpuscles radiating from the centre—the *Streptothrix actinomyces* (or ray fungus). Somewhat similar organisms are the *Streptothrix maduræ* (occurring in Madura foot), and the pathogenic streptotriches described by Foulerton and others. These all belong, provisionally, to the higher bacteria. Minute amœboid bodies termed *Plasmodia* (*Hæmatozoa*) are pathogenic in malaria, and parasitic amœbæ, twelve times the size of white blood-corpuscles, have been found in the intestines and fæces in cases of dysentery, and in pus from tropical abscesses of the liver associated with dysentery.

The origin of *cancer* is unknown. In its initial stages the disease is purely local, then gradually it spreads to the adjacent tissues, infecting also the lymph-glands which receive the lymphatics from the affected area, and ultimately general infection (dissemination) of the body follows. Thus it appears to be of parasitic origin and may eventually come to be defined as "a chronic infective disease due to a microparasite which selects an epithelial cell".

(Bland-Sutton). Modification of vestigial or embryonic cells and trauma have also been suggested as probable causes.

Organisms destitute of chlorophyll, having their habitat in living hosts, animal or vegetable, are termed *parasites*, while those living upon dead organic material are known as *saprophytes*. Many microbes are capable of fulfilling both parts, though not necessarily with equal facility. Parasites that have not been found to grow under any known conditions as saprophytes are distinguished as "obligate," others as "facultative." *Bacillus anthracis* is an example of a facultative parasite, and the unknown microbes of rabies and many other infective or inoculable diseases may be provisionally classed as obligate. Cultivation in artificial media, that is, a form of saprophytism, is essential for the complete testing of the pathogenic nature of a given microbe. Bacteria may therefore be classified as parasitic and saprophytic, or pathogenic and non-pathogenic. Other classifications may depend upon the characteristic growth of bacteria in artificial media in pure culture, and their effect upon such media, and whether they grow under aerobic or anaerobic conditions.

The action of microbes is essentially one of oxidation. As a rule carbonic acid gas is given off, but many known and unknown bodies are formed coincidently, which vary greatly with the pabulum as well as with the microbe. Among these are poisonous alkaloids (toxins), which, so far as certain pathogenic microbes are concerned, are usually to be regarded as the immediate agents in the production of disease-symptoms. They are soluble, and even when freed from their respective microbes have in certain cases been found to be capable of producing a slight and transient appearance of characteristic symptoms. They may also be protective against disease, and it has been shown, for example, that the injection of filtered fluid in which anthrax bacilli have been cultivated protects against subsequent or even coincident inoculation with virulent anthrax. Hankin isolated from cultures of the anthrax bacillus an *albumose*, injection of which into mice renders them insusceptible to anthrax. Brieger and Fränkel have isolated pathogenic albumoses from cultures of the specific microbes of diphtheria, enteric fever, cholera, and tetanus. Roux and Yersin believe the soluble poison to be a ferment, and Martin has shown that in anthrax and diphtheria the microbe produces such a ferment or *enzyme*, which reacts on the tissues to form *albumoses*, and that these break up into simpler bodies, which possess the specific toxic virulence and protective power.

Cultivation.—Microbes derive oxygen either from the air or from compounds containing oxygen; in the former case they are termed *aerobic*, in the latter *anaerobic*. Yeast (*Saccharomyces cerevisiæ*) is anaerobic, and acquires oxygen at the expense of the sugar, which is reduced to alcohol; the "vinegar plant," *Mycoderma aceti*, is aerobic, and oxidizes alcohol into acetic acid. Aerobic microbes grow best at the surface of a liquid, anaerobic organisms deeper down away from contact with air or aerated layers of fluid. The distinction is not absolute, and many microbes, as already mentioned, can exist under either condition (*facultative anaerobes*).

Besides oxygen, microbes require nitrogen, which some are able to take from salts, such as ammonium tartrate, while others can only assimilate it from albumin or gelatin. Carbon is necessary, and also inorganic salts, including sodium, potassium, and phosphoric acid. Cultivation media should be neutral or faintly alkaline.

Both liquid and solid media are used. Among fluid media are broths made from various kinds of meat, peptones and meat extracts, Pasteur's solution (water containing cane sugar, ammonium tartrate, and yeast-ash), Cohn's solution (water with ammonium tartrate, potassium phosphate, tricalcic phosphate, and magnesium sulphate), and bile-salt and sugar solutions. Some of the more common solid media are boiled potato, solid egg-albumin, blood serum, agar-agar, nutrient gelatin (gelatin with admixture of meat extract), bile-salt-glucose broth or peptone, lactose media, etc. The medium must be adapted to the organism.

After thorough sterilization by heat, media are kept in sterilized test-tubes, guarded, by means of sterilized plugs of cotton-wool, against infection by air-borne germs. Each tube may then be "inoculated" by means of a previously sterilized platinum wire charged with the microbes to be cultivated; the wool plug is removed momentarily for this purpose, and then replaced. Potato cultures are made by inoculating the freshly cut surface of a boiled potato cut in strips and placed in sterilized test-tubes. For plate-cultivation, a small portion of the liquid under examination is diffused through melted nutrient gelatin or other suitable medium, and then poured into a Petri plate (which is a flat, shallow glass dish having a glass cover), and allowed to solidify by cooling; protection from aerial germs is afforded by the glass cover. The temperature must be kept constantly at the point which experience has shown to be most favourable for the microbe in question. For this purpose an "incubator" is used, in which the temperature is regulated automatically. (Room-temperature or cool incubators are regulated at 18–22° C., and blood-heat incubators at 37–38° C. The temperature is controlled by thermo-regulators.)

Liquid media which solidify offer great advantages. If more than one variety of microbe is present, the resulting colonies tend to remain distinct, and it is comparatively easy to establish a pure cultivation of each by inoculating afresh from it. Plate-cultivations are especially useful in this way, since by regulating the proportions the distribution of the colonies may be made as sparse as is necessary. Accidental contamination by aerial organisms is readily prevented. Another important advantage is that pure cultivations upon solid media frequently exhibit naked-eye peculiarities of outline and characters of growth that are important as means of identification. Another method of obtaining a pure culture is adopted by cultivating under conditions inhibitory to some microbes, but not to certain others: this is effected by adding phenol (*Parietti*), taurocholate of soda (*McConkey*), crystal violet (*Drigalski* and *Conradi*), etc., or by maintaining the temperature at 45° C.

Among the **points of differentiation** for the separation of the large number of varieties of bacteria are the following: (*a*) Microscopic appearances, as to form, size, structure, movement; (*b*) effect of certain staining and decolorizing agents; (*c*) media in which growth occurs, and temperature required; (*d*) rate of growth; (*e*) macroscopic (and if necessary microscopic) appearance of cultivation in solid media, including form, colour, distribution (superficial or deep), liquefaction of gelatin, production of gas, acidity, toxins, etc.; (*f*) results of inoculation upon animals; and (*g*) agglutination tests.

Attenuation of virus has been effected in several ways.

1. **Subculturing from old cultures.**—Pasteur found that an organism retains its virulence unimpaired for a short time only if kept in sealed tubes, or if cultivated with a minimum interval between the successive cultures. If, however, the cultivation is allowed to remain for weeks or months without subculturing, the virus is attenuated, and, when inoculated, causes a mild but protective form of the disease.

2. **Cultivation at high temperatures.**—Pasteur prepared a "vaccine" (i.e. an attenuated virus) of anthrax by cultivating the bacilli for three weeks in air at 42–43° C. There is no visible change in the mode of growth during this period except that spores are rarely if ever formed, but spore formation is immediately resumed if the bacilli are transferred to a fresh culture at ordinary temperatures. The virus becomes more and more attenuated if the temperature is maintained, and in about a month the bacilli all perish. The attenuation is brought about more rapidly at higher temperatures; a few days suffice at 45° C., a few hours at 47° C., a few minutes at 50–53° C. The original virulence is regained speedily upon transferring the attenuated bacilli to fresh media at ordinary temperatures, if the attenuation has been rapid. If, however, it has been slow, it is difficult to restore the virulence, except by animal inoculation, and not always then.

3. **By heating or drying,** as in black-leg of cattle and rabid spinal cord.

4. **Cultivation in presence of inhibitory reagents.**—Klein cultivated anthrax bacilli in gelatin containing 0·0025 per cent. of mercuric chloride, and obtained an attenuated virus which for a time protected guinea-pigs. Cultivations from the attenuated virus were virulent. Other reagents, including potassium bichromate, phenol, and terchloride of iodine (for tetanus bacilli), have been employed in like manner; or the organism may be grown on a medium which is either slightly too acid or too alkaline.

5. **Transmission through insusceptible animals.**—Anthrax bacilli from sheep or cattle cause fatal anthrax if again inoculated upon susceptible sheep or cattle, or upon white mice; but bacilli taken from white mice produce only a transient illness in sheep, which, however, is protective. Assuming Jenner's view to be correct, vaccinia is an example of attenuation of virus, that of smallpox being so modified by transmission through the (insusceptible) cow as to produce a mild but protective form of the disease.

It must not be forgotten that the opposite of attenuation may also be obtained. Exaltation of virus results from early subculture on favourable media or the passage of the virus through susceptible animals.

These changes brought about in the laboratory by artificial means find a close parallel in the varying virulence of epidemic diseases. Sometimes the type, whether of smallpox, scarlet fever, diphtheria, or measles, is malignant and fatal, and at other times the same disease is so mild as to cause scarcely any mortality.

Toxins and their effect.—When a pathogenic organism grows in the body, it produces as a result of its metabolism certain poisonous substances termed *toxins.* These may occur as a direct result of the life of the bacillus, or as a result of a ferment produced by the bacillus. Toxins are of various kinds, and by their effect upon the blood and body tissues they cause the symptoms of disease. Fever is produced by the action of albumoses (bodies allied to the albumins) upon the heat-regulating centres in the brain. Albumoses also cause a number of other symptoms and poisonous effects. Toxins act, broadly speaking, in two ways. They have a local effect (as in the formation of an abscess owing to necrosis of proliferating cells) and a general effect. The latter is caused when toxins are absorbed and distributed generally throughout the body. When this occurs they produce degenerative changes in muscles, in organs, and in the blood itself. Of such a change diphtheria is an example. The bacillus occurs in a false membrane in the throat, and occasionally in other parts. It first causes the inflammatory condition giving rise to the membrane, and then it breaks it down. In the body of the membrane the bacillus appears to secrete a ferment which by its action and interaction with the body cells and proteins, chiefly those of the spleen, produces *albumoses* and an *organic acid* (*Martin*), which are the toxins. They are absorbed, and as a result we get the frequent pulse and high temperature of fever: the toxins irritate the mucous membrane of the intestine, and cause various fermentative changes in the contents of the bowel, and thus we get symptoms of diarrhœa: they penetrate the liver, spleen, and kidney, setting up fatty degeneration and its results in these organs: they finally affect many of the motor and sensory nerves, breaking up their axis-cylinders, and producing the characteristic paralysis. There is now some reason to believe that the diphtheria bacillus produces three separate poisons, causing respectively general intoxication, local œdema at the point of inoculation which may pass on to necrosis, and paralysis.

Toxins have sometimes been divided into *extracellular* (ferments, albumoses, and alkaloids) and *intracellular*, or poisons present in the body of the bacillus and not "available" if the bodies of the bacilli be filtered out.

The virus of *anthrax* produces albumoses, and an alkaloidal substance (*Martin*), the former causing fever, the latter œdema, congestion, and local irritation. Hankin holds that the bacillus first produces a ferment and then elaborates albumoses, and other authorities are undecided as to whether it produces a soluble poison or only an intracellular toxin. In *tetanus* Ehrlich has isolated a spasm-producing toxin (*tetano spasmin*), and a crude poison capable of destroying red blood-cells by hæmolysis (*tetanolysin*). The nature of the tetanus toxin (*tetanine*) is not determined, but it is known that it is a most powerful poison, probably less than $\frac{1}{250}$ grain being poisonous to man. Tetanus toxin has a marked affinity for the nervous system, though it exists in other organs from which it may be extracted by glycerin. In *typhoid fever* intracellular bacillary poisons exist, and a toxalbumin has been obtained which has pathogenic effects of an indefinite character. The *plague* bacillus and the *cholera* bacillus also contain intracellular toxins. In glycerin-bouillon the *tubercle* bacillus produces toxin, and the bodies of the bacilli are themselves toxic. Tubercle toxin forms a peculiar acid (which causes caseation), and other substances producing fever and convulsions.

The action of bacteria as disease-producers depends then (1) upon the effects of the presence of the bacteria themselves, (2) upon their power of forming, directly or indirectly, certain chemical organic products known as *toxins*, and (3) upon the individual attacked. The effects of bacteria, though very diverse, may be classified generally as of a *necrotic* or a *separative* character, leading to increased functional activity at first (such as phagocytosis), and subsequently to increased formative activity (such as cell growth and subdivision). In most diseases the lesion has a special site (as in typhoid fever) and the body generally is only affected indirectly. This localization may be due to specific action, or to point of entrance of the bacillus (as in malignant pustule). Secondarily to tissue changes, the body metabolism is affected owing to the absorption and distribution of toxins, and it is to this cause, as a rule, that the chief symptoms of disease are due. Finally, much depends upon the soil upon which the bacteria and their toxins are implanted. It must never be forgotten that the individual's body cells are an extremely important factor in the production and character of disease.

Protective effect. — An important general characteristic of specific diseases is their tendency, in the event of recovery, to protect the patient against a subsequent attack of the same disease. This statement must be taken in a modified sense as regards syphilis, leprosy, and the malarial diseases. The protection is perhaps most complete in smallpox, but in this, as in all others of the class, second and even third attacks are occasionally met with. In enteric fever, diphtheria, and influenza the protection is much less marked, and in erysipelas, phthisis, and septicæmia it can scarcely be said to exist. In all cases it diminishes with the lapse of time, its duration being dependent upon the nature of the disease, upon the amount of lesion (in vaccination, at all events), and probably upon idiosyncrasy. Klein has shown that protection against anthrax, though real, is very brief in guineapigs, and much more lasting in cattle. Various conditions affect both the onset and protectiveness of disease. Fatigue greatly increases the susceptibility of rats to anthrax. The presence of sugar in the tissues (due either to direct injection of sugar, or administration of phloridzin) lessens the resistance to glanders and to suppuration, but not to anthrax or tubercle. There are also examples of the virulence of a pathogenic microbe being intensified by the presence of an otherwise harmless germ. Little is known as to any protective power of one specific disease against another, unless vaccinia be regarded as absolutely distinct from smallpox. Erysipelas has been found experimentally to be protective against anthrax.

Four principal hypotheses, in some degree overlapping each other, have been advanced to account for the protection conferred by an attack of specific disease :—

1. The **exhaustion** or **pabulum** theory is that the microbes during the first attack remove some chemical substance necessary for their growth, the loss of this substance rendering further attack impossible. This view involves the improbable assumption that the human body contains a special and separate pabulum suited to each specific disease to which it is liable, since a disease is only protective against itself.

2. According to the **acclimatization** theory, the cells and tissues of the individual are in some way modified during an attack so as to be able to resist future invasions of the same microbe. The tissues, in short, have acquired a tolerance of the poison of a certain disease, and subsequently that infection does not produce the former symptoms of disease.

3. The **phagocyte** theory, somewhat allied to the theory of acclimatization, is based on Metchnikoff's observation that when virulent anthrax bacilli are inoculated into an insusceptible animal (such as a frog), the white (amœboid) blood-corpuscles absorb the bacilli bodily, and presumably destroy them. The same happens when attenuated virus is inoculated,

even into susceptible animals; the bacilli may be seen partially or wholly embedded in the amœboid corpuscles. When a susceptible animal is inoculated with virulent anthrax, however, few if any bacilli can be seen inside the corpuscles. The inference to be drawn from Metchnikoff's observations is that the amœboid corpuscles act as "phagocytes," or destroyers of pathogenic microbes; and that "protection" is largely, if not entirely, dependent upon this action. The same hypotheses may serve to account for the termination of an attack. It may be assumed that all the pathogenic microbes perish or are eliminated at the end of an attack of most of the infectious diseases, but pass into a quiescent stage in the intervals of malarial and relapsing fever. In tuberculosis, leprosy, and syphilis their development may be progressive.

In 1903 Wright and Douglas found that no phagocytosis occurred if the leucocytes were separated from the blood plasma. They concluded, therefore, that the leucocyte by itself was impotent, and that the phagocytosis was dependent upon some substance in the blood plasma. Subsequently they showed that this substance did not act directly upon the leucocytes, but by combining with the micro-organisms prepared them, so to speak, for destruction by the leucocytes, hence this substance in the plasma is termed *opsonin* (ὄψον, a sauce or relish). It follows that the amount of phagocytosis is an index of the quantity of opsonin, and does not directly represent the vital activity of the leucocyte. Opsonins are believed to be distinct from agglutinins and antitoxins, and possess apparently a high degree of specificity. In normal serum they are almost completely destroyed by heating for ten minutes at 60° C. The opsonic content of any blood is arrived at by comparing the amount of phagocytosis observed as a result of the activity of its serum with the amount of phagocytosis observed in the case of a normal serum used as a control. The figure so obtained is termed the "opsonic index" of the patient's blood; e.g. an opsonic index of 0·5 means that the blood contains one-half the normal quantity of that specific opsonin. The opsonic index is a test of considerable value in estimating the trend of immunization.

4. The **antitoxin** theory assumes that the first attack leaves in the system some direct or indirect product of the effect of the bacteria or their toxins (*antigen*) which inhibits any further multiplication. As a result of infection, specific antibodies are formed in the blood which have antitoxic power, or the power of destroying bacteria (*bacteriolysins*). Bordet showed that such bacteriolysis was due to two types of antibacterial bodies—one the *complement*, or *alexine*, present in normal blood-serum (rendered inert by heating to 56° C.), and the other the *copula* or *amboceptor* (able to resist heating at 56° C.), a "fixative" developed in immunized serum only. The serum of an "immunized" animal has also been found to possess properties enabling it to agglutinate bacilli or corpuscles (*agglutinins*), to destroy living cells (*cytolysins*), and to precipitate the albumins of the serum (*precipitins*). The agglutinating power of natural immunized serum is now used as an ordinary laboratory method of differential diagnosis (in typhoid, undulant fever, and dysentery). Complement fixation is similarly used, for example in syphilis (*see* p. 484). For bacteriolysins or hæmolysins to act it is essential that complement should be present for fixation purposes (*Bordet*).

Ehrlich's side-chain theory is an attempted explanation of these changes. He argued that a molecule of normal protoplasm is composed of a central atom cell with a large number of "side-chains" of atom groups. The central cell is the mother cell, the side chains are *receptors*, that is, cells having combining affinity with foodstuffs by which nutriment is brought to the mother cell. These receptors are of two kinds, those having power of combining with molecules of simple constitution, and those having power of breaking up compound bodies by ferment action for purposes of assimilation. Toxins are provisionally regarded by Ehrlich as possessing two kinds of elements, *haptophorous* (i.e. the atomic group responsible for union with side chains of cells) and *toxophorous* (i.e. the toxic atomic group). When introduced or occurring in the system, toxins are fixed to the receptors by the former, while the latter remain free and, if in sufficient number or quantity, produce toxic changes. If the dose of toxin is small, the mother cell throws off the receptor plus the toxin (R + T), which thus becomes free in the blood. The central atom group then produces new receptors, which in their turn are set free. Ultimately, the toxin being exhausted, there is over-generation of receptors and the excess of unfixed receptors becomes free in the blood, constituting *antitoxin* molecules. Thus, when forming part of the mother cell the receptors anchor the toxin, which sets up toxic effects, but when the receptors are free in the blood (R + T) we have an inert compound without toxic effect. This ingenious theory assumes that antitoxins are normally present in the body in varying degrees, and when stimulated by introduction of toxin become increased.

Such, then, are the hypotheses which have been suggested to explain immunity. They cannot at best be said to be more than theories, and new knowledge may substantially modify or even supplant them. At the present time Ehrlich's theory is generally accepted as explaining the production of immunity and allied phenomena. The antitoxin molecule has thus come to be looked upon as a protective substance, produced *in the body cells* as a result of toxic action, and held in solution in the blood serum, and there and elsewhere exerting its neutralizing influence by combining with the toxins. These antitoxic bodies gradually increase in the blood and tissues, and their action is believed to fall into two groups—(*a*) *antitoxic*, which counteract the effects of the poison itself; and (*b*) *antimicrobic*, which counteract the effects of the bacillus itself. Other authorities hold that the antitoxin is not antibacterial. In any case, antitoxin must be looked upon as a normal constituent of the living cells which is produced in increased quantity, and which combines with the toxin and neutralizes it. Of the chemical nature of toxins and antitoxins very little is known. Toxins, as we have seen, are probably of the nature of albumoses, and antitoxins probably have a molecule of greater size and may be allied to the globulins. Antitoxin has been shown to appear in the various secretions of the body as well as in the blood, though in a less concentrated state. The relation of the antitoxin to the toxin, and its mode of antagonism, are probably analogous to chemical union.

Immunity, therefore, depends upon some property in the living blood serum which opposes or annuls the products and action of the infecting organism. Buchner designated these protective bodies, held in solution in the blood, *alexines* (*complement* of Ehrlich), and regarded them as belonging to the albuminous bodies of the lymph and plasma. Alexines are *naturally* produced antitoxins; artificially produced antitoxins are *acquired* alexines, corresponding to "natural" and "acquired" immunity. The term *natural immunity* is used to denote natural resistance to some particular specific disease. It may be due to species of animal, to age, or to individual idiosyncrasies. For example, cholera and typhus fever, which affect man, do not affect the lower animals. Swine plague does not affect man. The white rat is immune to anthrax, which readily attacks cattle. *Acquired immunity* is a protection not belonging to the tissues of individuals naturally and as part of their constitution, but acquired during life in one, or both, of two ways:

either it may be an *involuntarily* acquired immunity, or a *voluntarily* acquired immunity—a natural attack of disease, or an artificial attack such as that due to inoculation. Smallpox and a number of other diseases rarely attack the same individual twice, because each of these diseases leaves behind it, so to speak, its antitoxic influence. Hence the individual has *involuntarily* acquired immunity against these diseases. An example of voluntarily acquired immunity occurs in the old method of preventive inoculation for smallpox, or *variolation*. This was an inoculation setting up an artificial and mild attack of smallpox by which the protective antitoxins of that disease were produced. It was a voluntarily acquired immunity. This form of artificial production of protection is *artificial immunity*. Where artificial immunity is produced by direct inoculation of attenuated bacteria in toxins (as in vaccination or Pasteur's treatment of rabies) the condition is known as *active immunity*; where antitoxins are inoculated (as in the antitoxin treatment of diphtheria) the condition is that of *passive immunity*.

Therapeutics of immunity.—Few recent advances in preventive medicine have been more remarkable than the application of the new knowledge respecting immunity to the treatment of disease. In smallpox, diphtheria, tetanus, rabies, snake-poison, anthrax, cholera, plague, enteric fever, tuberculosis, streptococcal infection, and other diseases, *serums* or *vaccines* have been discovered and are now in daily use in treatment, prophylactic or therapeutic, and some of them also in diagnosis. Subsequent reference will be made to these remedies as each disease is considered.

Preparation of antitoxic serums and vaccines.—Immunizing serums[*] are of two kinds, antitoxic and antibacterial. *Antitoxic serum* is usually derived artificially from the horse. A healthy animal is selected and tested by tuberculin (diagnostic of tuberculosis) and mallein (for glanders). It is then inoculated with a dose of attenuated toxin, and subsequently with gradually increasing doses of virulent toxin, producing slight febrile attacks, until a large degree of tolerance has been produced. The toxins used for injection are prepared by growing the organisms in suitable fluid media, and filtering off the bodies of the bacteria. When a sufficient degree of immunity is reached a few days are allowed to elapse, and then 16 to 20 pints of the horse's blood are withdrawn from the jugular vein, under antiseptic conditions, into sterilized flasks. After coagulation the serum (about half the volume of the blood) is decanted and mixed with a small quantity of antiseptic. The serum is then tested for the presence of organisms and toxic properties by incubation in favourable media and by animal inoculation. If the serum be germ-free and non-toxic it is ready for standardization, which is accomplished by inoculating a standard animal with a standard dose capable of neutralizing a given "minimal lethal dose" of toxin. In the case of diphtheria the death of a guineapig weighing 250 grm. on the fourth day is used as a standard, and equal quantities of toxin and antitoxic serum are inoculated to determine the capacity of the toxin to kill on the fourth day. A unit of antitoxin is that quantity of antitoxic serum which will exactly neutralize 100 minimal lethal doses. Antitoxic serums should be administered early, in large doses and of fresh preparation *Antibacterial serum* is made in a similar way, but the actual bodies of the bacteria are injected. In some antibacterial serums (streptococcic and pneumococcic) the presence of leucocytes seems necessary to the action of the serum

Vaccination is an inoculation of an attenuated virus. In *vaccine* treatment the patient is stimulated by inoculation to produce his own protective substances; in serum-therapy he receives protective substances formed in the body of another animal. Vaccines are prepared artificially from the strain of the bacterium producing the infection of the patient, which is isolated, cultivated under "optimum" conditions, and then killed in saline emulsion at its thermal death-point. The vaccine is then tested for sterility and preserved by the addition of antiseptic. Vaccines may be "autogenous" (prepared from the patient's bacillus) or "stock" (prepared from the same type artificially grown). The preparation of glycerinated calf-lymph and that of Pasteur's vaccine for rabies are described subsequently.

CHAPTER XIII

INFECTIVE DISEASES

SMALLPOX

SMALLPOX has been described more or less clearly in Eastern countries for nearly two thousand years, and more definitely in Europe since the sixth century. No part of the world is exempt from epidemic visitation; but in India and the Soudan it is so constantly prevalent that these may be regarded as endemic foci. Pandemic extension occurs from time to time, characterized by the enormous areas attacked, and by the malignant type of the disease. The last of these was that of 1871–2, which overran Europe and America, and caused in England alone 42,000 deaths during the two years.

The whole epidemic character of smallpox has completely changed since the introduction of vaccination. The "bills of mortality" show that upon the average 7 to 9 per cent. of the persons buried in London during the seventeenth and eighteenth centuries had died of smallpox, and in epidemic years the proportion often rose to 13, 15, or even 18 per cent. The only approach to this state of things since the introduction of vaccination was in the pandemic year, 1871, when 9·8 per cent. of the deaths in London were due to smallpox. The general mortality upon which this percentage is calculated is, of course, far smaller in proportion to population than in the last century. During the greater part of last century smallpox became somewhat prevalent in London every four or five years, but in the decade 1891–1900 it remained at a very low ebb, although it rose somewhat in the first half of 1901–10. The same remarks apply more or less to the other English towns, most of which suffered heavily in 1871–2, and with few exceptions have been unprecedentedly free from the disease in recent years. A severe epidemic occurred, however, in Sheffield in 1887–8, in the manufacturing districts of Yorkshire and Lancashire and at Gloucester in 1896, and throughout the country in 1902–3. The death-rate per million in England and Wales has fallen from 411 in 1871–5 to 0·38 in 1906–15.

Season.—The mortality curve for smallpox in England is above the mean from January to June, and below it from July to December. The New York curve does not differ essentially from this, but rises to a more definite maximum in May. In India the maximum is found to occur in the cold season, namely, in March or April. Soil does not appear to have any influence upon the prevalence of smallpox.

Air.—In 1884–5 it was found by Power that cases of smallpox in the surrounding districts followed the admission of acute cases into Fulham Hospital. He showed that, if the district were divided into zones, by means of circles drawn upon the map from the hospital as a centre, with radii of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 mile respectively, and an enumeration made of all the houses in each belt, and also of all houses invaded by smallpox, the proportion of invaded houses diminished as the distance from the hospital increased, and this relation held good in each "quadrant" of each zone (Fig. 59). Within the quarter-mile zone there was only one approach to the hospital, and this was in the N.W. quadrant. The distribution of cases in the several quadrants was not such as to suggest any relation to lines of traffic or ambulance routes. Power's conclusion was that diffusion only occurred when *acute* cases were aggregated, and perhaps only under certain atmospheric conditions that it is impossible as yet to define.

Barry found a similar radiation of infection from hospital upon a larger scale in the Sheffield epidemic

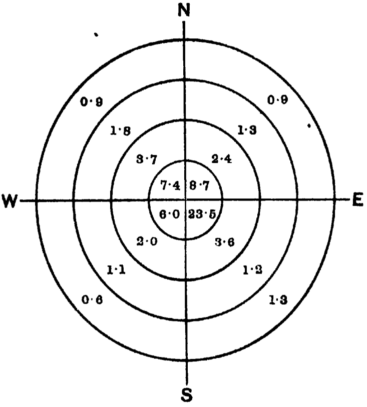

Fig. 59.—Incidence of smallpox upon district around Fulham Hospital. May 25th, 1884, to September 26th, 1885.

The figures show the percentage of houses invaded in each quadrant and quarter-mile zone.

of 1887–8, but the possibility of personal convection could not be entirely excluded. Similar observations with similar results, namely, a graduated intensity of smallpox incidence as distance between a smallpox hospital and a populous neighbourhood became less, have been made at Oldham in 1893; Warrington, 1892–3; Bradford, 1893; Glasgow, 1900–1; and the

Orsett Union, adjoining the site of the smallpox hospital ships in the Thames, from 1884 to 1902. These and other careful investigations leave little room for doubt that aggregation of cases of acute smallpox in the midst of populous areas favours the spread of the disease.

Sanitation.—Compared with infection, the influence of sanitary conditions is secondary, but they exert an indirect effect in time of epidemic upon local incidence. Filth, overcrowding, poverty, and the absence of effective isolation are undoubtedly favourable to the spread of the disease. Neither water nor milk has been shown to convey the infection of smallpox.

Age and sex.—The mortality from smallpox is greater among males, not only at all ages taken together, but also, with few exceptions, at each age-period. The exceptions are the second and third years of life, and the tenth to the fifteenth year, at all of which, from some unexplained cause, the female mortality slightly exceeds the male.

The relation to age has to be considered with reference to vaccination. In pre-vaccination times, as McVail has shown from the Kilmarnock registers, 90 per cent. of the deaths were at ages below 5 years, the actual maximum being in the second year. Under present conditions, the deaths under 5 years, being practically limited to unvaccinated children, constitute only 30 per cent. of the total smallpox deaths, and in this age-period the greatest mortality occurs in the first year, being, indeed, highest in the first three months of life. It diminishes steadily from this point until about the fifteenth year, rises to a second maximum about the twenty-fifth year, and thenceforward diminishes again.

Race.—Coloured races, and especially negroes, have a peculiar susceptibility to smallpox. They take it more readily, and suffer a heavier case-mortality, than white races, apart from all question of vaccination.

The **incubation period** is usually 12 days, or, counting to the appearance of the rash, 14 days, so that the rash is seen on the fifteenth day, on the same day of the week that the infection was acquired. There are, however, exceptions to this rule. Inoculation of smallpox is followed by constitutional symptoms on the seventh or eighth day, and the general rash appears on the tenth or eleventh. Even after infection by more ordinary means it is stated that the latent period may range from 7 to 18 days; and the rash is often delayed until the fourth day (i.e. the third *after* onset) instead of appearing on the third.

Infection is given off, presumably by the breath, from the earliest onset. The exhalations, the vesicles, pustules, and scabs are also highly infectious. The virus may be carried by air-currents, as already mentioned. It readily lodges in clothing, and retains its vitality tenaciously; hence outbreaks are liable to occur in paper-works and other manufactories where rags are employed. Isolation should be maintained for at least three weeks in the mildest case, and always until every scab has disappeared—a process which, in confluent cases, will take six weeks, and often considerably longer. After exposure to infection, a quarantine of 17 days—to allow a margin over the fortnight—is sufficient. Second attacks are rare, except after several years' interval. Third attacks are not unknown.

Diagnosis.—The medical officer of health is not infrequently consulted as to the diagnosis of variola, and it may be desirable therefore to add here the main points to be borne in mind as characteristic of the disease:—

Sudden attacks of fever, headache, vomiting, backache (most marked in the lumbar and sacral regions) generally begin from 12 to 14 days after infection. Rigors are often present.

Vomiting and retching are sometimes severe. In children (and even in adults occasionally) these initial symptoms may be obscured by drowsiness.

The initial symptoms last two or three days before the characteristic rash appears. But in some cases accompanying these symptoms are various forms of mild eruptions, which may simulate measles or scarlatina. Such eruptions are frequently localized to different parts of the body.

The characteristic eruption of smallpox appears about two days after the onset of the backache, fever, etc. It consists at first of a number of small red pimples or spots, which gradually enlarge and become hard and "shotty" to the touch. After they have been out for about 48 hours they begin to become small bladders or vesicles, containing at first clear, and, later on, purulent matter (pustules). They are about the size of a split pea, are surrounded by a thin red zone (or areola), are definitely raised above the level of the skin, often assume the colour of dull pearl, and in many cases show a central depression (umbilication). About the eighth or ninth day the pustules begin to dry up, so that, from the first appearance of the rash, the successive stages of pimple, vesicle, and pustule occupy about ten or eleven days. Simultaneously with its appearance on the skin the eruption appears on the mucous membrane of the mouth and palate.

In persons who have been vaccinated the rash is somewhat modified (varioloid) and comes out more rapidly; the vesicles are smaller and less abundant, not so much depressed in the centre, and may not become pustular.

An important point is *the distribution of the rash.* The first spots generally come out on the face, particularly on the forehead and around the lips. Almost immediately afterwards they appear on the limbs, being particularly marked on the wrists and ankles. Afterwards the rash appears on the back, whilst the skin on the front of the chest is less affected and the skin of the abdomen least. A further point is that, as a rule, when the rash comes out the temperature falls and the patient feels better. In rare instances the rash is almost entirely suppressed, and therefore in times of epidemic the appearance of the premonitory symptoms alone should arouse suspicion.

The three most important aids to correct diagnosis are—the premonitory symptoms, the character of the rash, and the distribution of the rash.*

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* *See* "The Diagnosis of Smallpox," by T. F. Ricketts, in which this subject, particularly the diagnostic significance of the distribution of the rash, is worked out in detail.

Precautionary measures to be taken in case of an outbreak of smallpox include—(1) prompt *notification* of cases, suspected cases (and, if necessary, of chickenpox); (2) immediate and rigid *isolation* in hospital; (3) thorough *disinfection;* (4) tracing and *supervision of all contacts*; (5) immediate *vaccination* or *revaccination* of all persons who have been exposed to risk of infection, however remotely, those only being excepted who have recently (say within four years) undergone successful vaccination, or who bear marks of recent smallpox. Vaccination within a day or two of exposure, and followed by a normal reaction, is a certain preventive (*Ricketts*). No reliance can be placed upon verbal assurances as to previous attacks, or even as to vaccination, and after a time the protection of previous smallpox, as well as of vaccination, may vanish.

The pathogenic microbe of smallpox has not yet been isolated. Various observers have described bacilli, micrococci, and protozoa which have been held to have etiological significance.

Inoculation of smallpox (*variolation*), already referred to (p. 382), was generally practised in England in the eighteenth century, having been introduced from the East in 1721 by Lady Mary Wortley Montagu. It seems to have been customary to inoculate from the primary vesicle, not from the secondary rash. Mild cases were selected, and the lymph was taken before suppuration set in. The fatality (2 or 3 per cent.), though far lower than that of "natural" smallpox, was by no means trifling, and the readiness with which the risk was incurred is a strong illustration of the magnitude of the danger to which it was the only known alternative. It was superseded by vaccination, and was finally forbidden by law in 1840.

Vaccination, introduced by Jenner in 1796, gradually superseded inoculation during the earlier part of the last century. It was provided gratuitously by the first Vaccination Act of 1840, made compulsory in 1854, and systematically enforced by paid vaccination officers from the time of the pandemic in 1871. Under the Act of 1898 more latitude has been allowed to the conscientious objector (*see* p. 403).

The following table presents a return of smallpox mortality before and after vaccination periods :—

Period before vaccination.	Period after vaccination.	Locality.	Mean annual small-pox mortality per 1,000.	
			Before vaccination.	After vaccination.
1777-1806	1807-1850	Lower Austria	2·48	0·34
1777-1806	1807-1850	Upper Austria and Salzburg	1·42	0·50
1781-1805	1810-1850	Berlin	3·44	0·18
1774-1801	1810-1850	Sweden	2·05	0·16
1751-1800	1801-1850	Copenhagen	3·13	0·29

Although such figures present striking evidence of the general effect of vaccination upon mortality, it is necessary to examine the particular effect as illustrated in the age-incidence both of mortality-rate and attack-rate. The first table is as follows :—

DEATH-RATES FROM SMALLPOX, PER 1,000 LIVING AT EACH AGE-PERIOD.*

	All Ages.	0–5.	5–10.	10–15.	15–25.	25–45.	Over 45.
1847–1853. Vaccination gratuitous but optional . .	0·305	1·617	0·337	0·094	0·109	0·066	0·022
1854–1871. Vaccination compulsory but not efficiently enforced .	0·223	0·817	0·243	0·088	0·163	0·131	0·052
1872–1891. Vaccination enforced .	0·089	0·177	0·095	0·054	0·097	0·086	0·038

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* Reg.-Gen. 43rd Ann. Rep.; and Foster, *British Medical Journal* 1893, i. 1060. The ages were not abstracted before 1847.

This table shows that each extension of vaccination was attended with a reduction in the smallpox mortality, in which, however, the different ages by no means shared equally. The reduction was greatest at the ages of highest mortality—that is, among children under 10 years of age—while at ages over 15 the change was comparatively slight. In the third period the latter no longer included, as in former generations, a large proportion protected by non-fatal attacks of smallpox undergone in early life, and on the other hand the protection due to infantile vaccination had had time to fade. Moreover, even unvaccinated persons had, under the new conditions, a better chance of escaping smallpox until adult life. The enormous reduction in mortality among young children whose vaccination was recent speaks for itself, and it must not be forgotten that the mortality at ages under 5 years occurs among the unvaccinated residuum, the vaccinated being practically exempt, as will be seen presently.

Other illustrations of the great change in the age-incidence of smallpox may be given. At Kilmarnock, from 1728 to 1764, there were 622 deaths from smallpox, of which 563, or 90 per cent., were at ages below 5 years. The corresponding proportion in England from 1871 to 1880 was 30 per cent. Buchanan* gives further instances in the following table, with an analysis of the age-incidence of smallpox mortality in London in 1884 upon the vaccinated and unvaccinated, *separately*, from which it is manifest that the old conditions remained unchanged among the unvaccinated, except that the protection which the rest of the community had acquired lessened the probability of exposure to infection.

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* Report of the Medical Officer to the L.G.B. for 1884.

CONTRIBUTION OF VARIOUS AGES TO 100 SMALLPOX DEATHS AT ALL AGES.

	Geneva, 1580–1760.	Kilmarnock. 1728–64.	Paris, 1842–51.	London, 1848–51.	London, 1884.		
					Un-vaccinated.	Vaccinated.	Whole community.
0-10 years	96·1	98·8	39 7	81·5	61·2	8·6	34·3
10-20 ,,	2·6	0·5	13·3	5·9	14·6	17·8	17·0
20-30 ,,	1·0	0·7	32·9	8·3	10·8	31·9	21·3
30-40 ,,	0·3	—	11·0	3·2	7·2	22·1	14·2
Over 40 ,,		—	3·1	1·1	6·2	20·1	13·2
	100·0	100·0	100·0	100·0	100·0	100·0	100·0

An analysis of the returns of the 5,683 smallpox deaths in London during the ten years 1879–88, as given by the Registrar-General, yields the following results:

AGES.	Of 1,406 stated to be *vaccinated.*	Of 2,265 stated to be *un-vaccinated.*	Of 2,012 vaccination not stated.	Of the total 5,683, irrespective of vaccination.
	Per cent.	Per cent.	Per cent.	Per cent
0 to 10 years . .	8·4	56·0	35·0	36·8
10 to 20 ,, . . .	16·0	17·2	14·7	16·0
Over 20 ,, . .	75·6	26·8	50·3	47·2

Confirmatory evidence, if needed, is afforded by Barry in reference to the Sheffield epidemic of 1887–8

SHEFFIELD, 1887–8.—SMALLPOX ATTACKS AND DEATHS (PER 1,000 PERSONS OF EACH CLASS STATED).

	Attack-rate.		Death-rate.	
	Vaccinated.	Unvaccinated.	Vaccinated.	Unvaccinated.
0-10 years	5	101	0·1	44
Ditto, living in invaded houses	78	869	1	381
Over 10 years . . .	19	94	1	51
Ditto, living in invaded houses	281	686	14	371
All ages	15·5	97	0·7	48
Ditto, living in invaded houses	280	760	11	372

From these statistics it appears that the vaccinated part of the population had, as compared with the unvaccinated, *at ages below* 10 *years*, a 20-fold immunity from attack, and 480-fold security against death from smallpox; *at ages above* 10 *years*, a 5-fold immunity from attack, and 51-fold security against death from smallpox; *at "all ages,"* a 6-fold immunity from attack, and a 64-fold security against death from smallpox.

As regards London, the proportion of smallpox deaths to deaths from all causes is available as a measure of the prevalence of the disease before and after the introduction of vaccination, which came gradually into operation at the beginning of the nineteenth century. From the "bills of mortality" it appears that during the thirty-one years 1770–1800 smallpox caused 59,253 out of the 626,530 deaths in London, or 9·4 per cent. In the thirty-one years 1801–31 the proportion was 4·6 per cent. From 1832 to 1837 no returns are obtainable; but for the thirty-one years 1838–68 the proportion was 1·4 per cent. Even in 1871, when the pandemic wave reached London the deaths from smallpox were only 9·8 per cent. of the total deaths, a proportion very little in excess of the *average* which prevailed between 1770 and 1800.

Thus it will be seen that the greater susceptibility of the unvaccinated to the smallpox virus is manifested not only in a greater liability to attack, but in a higher case-mortality.

It may be convenient to summarize the evidence as follows:

A. *As regards vaccinated and unvaccinated populations respectively.*—(1) In pre-vaccination times the heaviest incidence of smallpox was upon childhood. (2) In the unvaccinated part of the community it is so still. (3) Among vaccinated persons childhood is exempt, and smallpox is only fatal in later years, when the protective influence of vaccination has faded. (4) In a mixed community (vaccinated and unvaccinated) both these effects are apparent, the heavier incidence upon the unvaccinated compensating for their scanty numbers. (5) The immunity at early ages among the vaccinated may be extended indefinitely by revaccination. (6) In every epidemic —if the numbers are sufficiently large to preclude fallacy— the unvaccinated suffer more attacks *in proportion to their numbers* than the vaccinated, and (7) a larger percentage of the attacks are fatal. (8) Among the vaccinated who suffer from smallpox in later years, the proportion of fatal to non-fatal attacks diminishes as the number or area of the cicatrices increases.

B. *As regards entire populations.*—(9) The introduction of vaccination has in all cases been followed by a lowered average incidence of smallpox. (10) Each extension of compulsory vaccination has led to a further reduction. (11) Compulsory revaccination when tried has almost entirely suppressed smallpox.

Care must be taken not to exaggerate the importance of infantile vaccination as the method of protecting a community. In recent years, in many districts, not more than 10 or 20 per cent. of the children are vaccinated, and yet the disease has remained quiescent or absent. Even in times of epidemic, prompt isolation, effective treatment, and supervision of contacts should be carried out in conjunction with vaccination measures. A complete system of infantile vaccination must always be followed by revaccination.

The character and area of the vaccination. The quality of vaccination also—that is, the number, area, and character of the cicatrices—has an important bearing upon the degree and permanence of the protection afforded. Both of these points come out clearly in all large hospital statistics, of which the following two examples will suffice:—

Case-mortality in relation to quality of vaccination and to age, based upon an analysis of 10,403 *cases in Metropolitan Smallpox Hospitals.* (GAYTON.)

Ages.	Vaccinated. Good marks.			Vaccinated. Imperfect marks.			Said to be vaccinated. No marks.			Unvaccinated.		
	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.	Cases.	Deaths.	Case Mortality.
0- 5	51	0	0·0	182	21	11·5	128	47	36·7	677	388	56·6
5-10	267	2	0·7	714	48	6·7	325	87	26·8	1,187	568	47·4
10-20	1,045	17	1·6	1,976	98	5·0	419	81	19·5	521	160	30·7
20-40	725	37	5·1	1,898	258	13·6	420	140	33·3	382	181	47·4
Over 40	48	6	12·5	266	51	19·2	131	44	33·8	79	34	43·0
All ages	2,085	62	3·00	4,854	455	9·00	1,295	352	27·0	2,169	938	43·0

Case-mortality in relation to number of vaccine cicatrices.
(MARSON.)

	Per cent.
Unvaccinated	35½
Stated to be vaccinated, but without cicatrices .	21¾
Having one cicatrix	7½
Having two cicatrices	4⅛
Having three cicatrices	1¾
Having four or more cicatrices	¾

Vaccination is protective against itself as well as against smallpox. Any number of "insertions" may be made at the time of vaccination. Whether one vesicle is produced or a dozen, the protection of the individual is absolute for the time being, but all experience goes to show that the *duration of the protection is limited*, and is directly proportionate to the number and area of cicatrices produced. Hence it is desirable to vaccinate in at least four places, and the total area of the cicatrices should not be less than half a square inch. The return of the Metropolitan Asylums Board for the smallpox epidemic in London, 1901–2, respecting this point, is given here, and a study of it will amply prove the claim made.

		Admissions.	Deaths.	Mortality per cent.
Vaccinated cases—				
Area of cicatrices	Half square inch and upwards	5,163	379	7·34
	One-third but less than half square inch . . .	835	131	15·69
	Less than one-third square inch	860	162	18·87
	Not recorded . . .	87	33	37·93
Totals of vaccinated class .		6,945	705	10·15
Unknown and doubtful class. .		436	171	39·22
Unvaccinated class. . . .		2,277	752	33·06
Grand totals		9,658	1,628	16·87

Revaccination.—As the protective influence of the primary vaccination fades, a time arrives when revaccination becomes possible. Comparatively few persons are insusceptible to revaccination after the lapse of ten or twelve years; many "take" readily within five years, although the primary cicatrices may be good. The course of revaccination in the majority of persons is different from that of the primary operation, being more rapid, and often failing to exhibit some of the typical stages. If, however, the former protection has entirely disappeared, the course of revaccination may be identical with that of a primary vaccination.

Revaccination renews in all respects the immunity given by primary vaccination. As regards entire populations, the results of general, if not universal, revaccination are shown in the following figures, taken from the report of the German Vaccination Commission of 1884. After the pandemic of 1870-74, revaccination was made compulsory in Germany *only*, and smallpox has never become seriously epidemic during the years that have since elapsed; while in other countries the incidence continued much as in the period before 1870.

SMALLPOX DEATH-RATES.

	Austria.	Prussia.*	Berlin.*	Hamburg.*	London.	Paris.	Vienna.
1870	0·30	0·175	0·22	0·25	0·30	5·46	0·46
1871	0·39	2·432	6·32	10·75	2·42	?	0·74
1872	1·90	2·624	1·38	0·95	0·53	0·06	5·86
1873	3·23	0·337	0·11	0·008	0·04	0·01	2·28
1874	1·78	0·095	0·024	0·005	0·02	0·02	1·35
1875	0·58	*0·036*	*0·051*	*0·000*	0·01	0·13	1·18
1876	0·39	*0·031*	*0·018*	*0·018*	0·20	0·20	1·67
1877	0·53	*0·003*	*0·004*	*0·012*	0·70	0·07	0·84
1878	0·61	*0·007*	*0·007*	*0·002*	0·38	0·04	0·75
1879	0·51	*0·013*	*0·007*	*0·000*	0·12	0·45	0·46
1880	0·64	*0·026*	*0·008*	*0·000*	0·12	1·09	0·78
1881	0·83	*0·036*	*0·047*	*0·022*	0·61	0·49	1·28

* Italic figures are used for the years in which compulsory revaccination was in force.

The German Vaccination Law was passed in 1874, compelling vaccination and revaccination. Infants must be vaccinated before the end of the calendar year following the year of birth, and *all* children must be revaccinated in their twelfth year. Obedience to this law is enforced by fine or imprisonment. So completely is this system worked, that there is less need for the strict isolation of smallpox than in England. For instance, in Germany, the rare cases of smallpox are placed in pavilions of general hospitals, not in separate smallpox hospitals. The population of Germany a few years ago was 56 millions, and from 1891 to 1902 inclusive there were 607 deaths recorded as due to smallpox. The smallpox deaths during the same period in England and Wales (population 32 millions) were 6,761. If the ratio had been the same in England as in Germany, there would have been only 350 deaths.

Barry shows that in the Sheffield epidemic the revaccinated had a great advantage over the rest. Of 8,198 persons revaccinated prior to the epidemic, 25 were attacked and 1 died, the attack-rate being therefore 3 per 1,000, and the death-rate 0·1. Among 56,233 persons revaccinated during 1887–8, 2 were doubtfully attacked and none died.

The practice of vaccination.—The vaccine virus is that of cowpox or vaccinia, a disease formerly prevalent among cattle, but now rarely met with. It occurs in the form of vesicles upon the teats and udder in cows. The virus is inoculable upon human beings as well as cows, and this inoculation constitutes vaccination. Goats also are susceptible. No person is insusceptible except as the result of previous vaccination or an attack of smallpox.

Jenner believed that vaccinia was smallpox modified by transmission through the cow, a form of attenuation very similar to that which we now know to be possible as regards many other diseases. Cowpox, formerly common, has become rare among cattle coincidently with the reduction in human smallpox due to vaccination. The limitation of the eruption to the teats and udders of cows suggests contact with the hands of milkers as a means of inoculation. It is difficult to inoculate cows with smallpox, but in one form or another it has been achieved by Ceely, Badcock, Voigt and Chaveau, resulting in various forms of cowpox.

Primary vaccination in the human subject is followed on the third day by a papule, which on the fifth or sixth day is vesicular. On the eighth day the vesicle is mature; it is greyish, elevated, tense, loculated, and contains a clear viscid lymph which exudes when the vesicle is pricked. On the ninth day inflammatory changes set in; the lymph begins to contain pus, and a reddish "areola" surrounds the vesicle. Slight constitutional symptoms are common at this stage. The vesicle becomes a pustule, begins to dry up about the tenth day, and forms a dark scab about the fourteenth. The scab falls off in the fourth week, leaving a permanent scar which should be depressed and pitted.

Vaccination by human vaccine may be carried on from arm to arm for an indefinite number of years without having recourse to the cow again. The lymph should always be taken on the eighth day (that is, exactly a week after the vaccination) from normal and unbroken vesicles. No lymph should be collected after a revaccination, or from an unhealthy subject, or from vesicles showing any sign of inflammatory action. By far the surest plan is to vaccinate directly from the vesicle, but the lymph may be sealed in capillary tubes or dried upon ivory points, and retains much of its efficacy for a considerable time.

Vaccination by calf-lymph is now in use upon a large scale, owing partly to a popular suspicion that the current arm-to-arm vaccination is losing its power, but chiefly to the fear of the virus of syphilis or other malady being inoculated with the lymph from diseased human subjects. There appears to be no difference either in the course of the symptoms or in results between ordinary arm-to-arm vaccination and vaccination from the calf.*

Protection of vaccination.—The incubation of vaccinia being shorter than that of smallpox, it is possible to modify or even entirely prevent an attack of smallpox by vaccination performed some days after infection. This is especially the case with revaccination, the incubation of which is often shorter than in primary vaccination.

Successful vaccination within three days after exposure to infection will prevent the appearance of symptoms, and it is probable that the attack will either be arrested or modified by vaccination as late as the fifth or even sixth day. The proof of this rests upon the observation that attacks of smallpox may, and do, occur within six days of vaccination in persons who have been many days previously exposed to infection, but the few attacks that occur between six and nine days after *successful* vaccination are mild, and practically none commence later. The usual incubation period of smallpox, it will be remembered, is twelve days.

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* *Glycerinated calf-lymph* is now prepared as follows: A calf, aged three to six months, is kept in quarantine for a week. If then found upon examination to be quite healthy, it is removed to the vaccinating station, and the lower part of its abdomen antiseptically cleaned. The animal is now vaccinated upon this sterilized area with glycerinated calf-lymph. After five days the part is again thoroughly washed, and the contents of the vesicles, which have of course appeared in the interval, are removed with a sterilized sharp spoon, and transferred to a sterilized bottle. This is now removed to the laboratory, and the exact weight of the material ascertained. A calf thus vaccinated will yield from 18 to 24 grams of vaccine material. This is thoroughly triturated and mixed with four times its weight of a sterilized solution of 50 per cent. chemically pure glycerin in distilled water. The resulting emulsion is aseptically stored in sealed tubes in a cool place. At intervals during four weeks it is carefully examined bacteriologically until by agar plates it is demonstrably free from extraneous organisms, when it is ready for distribution. "Chloroform" calf-lymph is also used. It is prepared in the same way, but charged with vapour of chloroform for purposes of rapid sterilization.

The Royal Commission on Vaccination, 1896, concluded that the protection vaccination affords against smallpox may be stated as follows:—

"(1) That it diminishes the liability to be attacked by the disease. (2) That it modifies the character of the disease and renders it less fatal and of a less severe type. (3) That the protection it affords against attacks of the disease is greatest during the years immediately succeeding the operation of vaccination. It is impossible to fix with precision the length of this period of highest protection. Though not in all cases the same, if a period is to be fixed, it might, we think, fairly be said to cover in general *a period of nine or ten years.* (4) That after the lapse of the period of highest protective potency the efficacy of vaccination to protect against attack rapidly diminishes, but that it is still considerable in the next quinquennium, and possibly never altogether ceases. (5) That its power to modify the character of the disease is also greatest in the period in which its power to protect from attack is greatest, but that its power thus to modify the disease does not diminish as rapidly as its protective influence against attacks, and its efficacy during the later periods of life to modify the disease is still very considerable. (6) That revaccination restores the protection which lapse of time has diminished, but the evidence shows that this protection again diminishes, and that to ensure the highest degree of protection which vaccination can give the operation should be at intervals repeated. (7) That the beneficial effects of vaccination are most experienced by those in whose case it has been most thorough. We think it may be fairly concluded that where the vaccine matter is inserted in three or four places it is more effectual than when introduced into one or two places only, and that if the vaccination marks are of an area of half a square inch they indicate a better state of protection than if their area be at all considerably below this."

The **Vaccination Acts** of 1867, 1871, and 1874 have been modified by that of 1898. In general, a child must be vaccinated within six months of birth. The parent is relieved from obligation if within four months after the child is born he satisfies a magistrate that he conscientiously believes that vaccination would be prejudicial to its health.* And even in the absence of such an exemption, an order under the 1867 Act directing that a child be vaccinated cannot be made upon any person who has previously been convicted of non-compliance with a similar order relating to the same child. It is the duty of the public vaccinator, if the parent so requires, to attend the child at its home. If a child is not vaccinated within four months of its birth, the public vaccinator is to visit the home, after giving at least twenty-four hours' notice, and offer to vaccinate with glycerinated calf-lymph or such other lymph as the **L.G.B.** may provide. In either case, if he finds that owing to the condition of the house, or recent prevalence of infectious disease in the district, the operation cannot safely be performed, he is not to vaccinate, but must give a certificate of postponement, and inform the **M.O.H.**†

Public vaccinators are to use only glycerinated calf-lymph, or other lymph supplied by the **L.G.B.**, and must keep registers from which the origin of the lymph used in each operation can be identified. The Instructions require the greatest care as to cleanliness and sterilization of instruments used, and aseptic precautions at all stages. "The public vaccinator must aim at producing four separate good-sized vesicles or groups of vesicles, not less than half an inch from one another. The total area of vesiculation resulting from the vaccination should not be less than half a square inch."

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* The Vaccination Act, 1907, provides for this claim to be made as a statutory declaration by the parent to the vaccination officer.

† The **L.G.B.** direct that, "except so far as any immediate danger of smallpox may require, the public vaccinator must vaccinate only subjects who are in good health. As regards infants, he must ascertain that there is not any febrile state, nor any irritation of the bowels, nor any unhealthy state of the skin, especially no chafing or eczema behind the ears or in the groin, or elsewhere in folds of skin. He must not, except of necessity, vaccinate in cases where there has been recent exposure to the infection of diseases such as measles, scarlatina, or diphtheria, nor where erysipelas is prevailing in or about the place of residence."

The **L.G.B.**, in the event of serious risk of outbreak of smallpox or other exceptional circumstances, may require the Guardians to provide vaccination stations, and may temporarily and locally modify the obligation upon the public vaccinator to visit otherwise than by request. Any **S.A.** maintaining a hospital for smallpox must keep a register of patients, showing name, age, address, and condition as to vaccination. The entries are to be made at the time of admission, and the register is to be accessible to the public.

A child must be vaccinated within six months of its birth unless (*a*) the parent obtains a certificate of exemption, or (*b*) the child dies, or (*c*) is attacked by smallpox within that period, or (*d*) three or more unsuccessful attempts at vaccination have been made,* or (*e*) a medical certificate of postponement (for not more than two months at a time) is given on the ground of ill-health, or of recent prevalence of infectious disease in the district, or of the condition of the house in which the child resides. Certificates of successful vaccination, or attack of smallpox, or of insusceptibility to vaccination, or postponement of vaccination, can be given by any registered practitioner.

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* In this event insusceptibility is inferred; but out of 38,000 primary vaccinations Cory failed in only one instance, and in that one he had no opportunity of making a third attempt.

Revaccination is entirely optional, but persons over 12 years of age are revaccinated gratuitously by the public vaccinator, and if there is immediate danger of smallpox the age-limit is reduced to 10 years.

The administration of the Vaccination Acts, subject to the control of the **L.G.B.**, is entrusted to the Poor Law Guardians, not to the **S.A.** as such. Instructions and blank forms of certificate are issued by the sub-registrars to the parents at the time of registration of birth.

VARICELLA

Chickenpox was only clearly distinguished from smallpox in the last century, but beyond a certain superficial resemblance there is nothing in common between the two diseases. Varicella occurs as an epidemic, which not infrequently coincides with smallpox outbreaks, and adds to the difficulty of diagnosis of mild cases of the latter. Persons of all ages are liable to attack, but children more than adults. The mortality is practically *nil*, a fatal result being unknown except in cases almost moribund from other causes, or in cases of *varicella gangrenosa*. Nothing is known of the conditions that determine the appearance of this rare and malignant type of varicella in individual cases during an outbreak of ordinary character.

The latent interval is very commonly a fortnight. The characteristic vesicular eruption, which may be very profuse and widely distributed, is thickest upon the back and shoulders. The vesicles are not usually umbilicated, although this is not a reliable point for diagnostic purposes, and among them are some that are aptly compared to drops of scalding water upon the skin, there being no induration around them. At other times varicella spots simulate smallpox more closely, but there is almost always a want of uniformity in size, appearance, and stage of development. The premonitory symptoms (vomiting, backache, anorexia, etc.) that accompany the onset of smallpox only, the distribution and appearance of the rash, the relation to vaccination, and the history of exposure to one or other kind of infection will seldom fail to make the diagnosis clear.

The infection of varicella is active from the first onset, and is readily imparted by contact or by means of fomites. The mode in which it is given off is unknown, but the breath is the most probable. Attempts have been made to inoculate from the vesicle, but without success. Second attacks are rare.

A quarantine of 18 days is sufficient after exposure to infection; after an attack, isolation should be kept up until all scabs have disappeared. In times of smallpox epidemic the L.G.B. or the County Council or S.A. may make chickenpox temporarily notifiable in order thereby to bring to light cases of smallpox simulating varicella.

MEASLES

Measles became clearly differentiated from smallpox and scarlet fever in the seventeenth century. No country or race appears to be exempt from it, and it has no demonstrated relation to climate. Some dependence upon meteorological conditions may be inferred from the fact that the colder months, even in the tropics, are favourable to the rise and spread of measles epidemics. In London the seasonal curve of mortality shows two maxima, a principal one in December and a lesser one in June, the minima occurring in February and September.[*] The influence of age as regards liability to attack has not been worked out, but the mortality from measles is greatest in the second year of life, and rapidly falls in every succeeding year. Sixty per cent. of the deaths occur during the first two years of age, 75 per cent. in the first three, and upwards of 90 per cent. under five years. Thompson has shown that from 5–10 years of age the attack-rate is 62 per 1,000 living, the death-rate 0·7 per 1,000 living, and the fatality-rate 11 per 1,000 attacked; whereas under 5 years of age the attack-rate is 137 per 1,000 living, the death-rate 11·6 per 1,000 living, and the fatality-rate 85 per 1,000 attacked. The mortality is greater among females at all ages above 5 years, but greater among males up to that point, so that upon the whole the female mortality is lower than the male. It is highest in urban districts.

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[*] The winter maximum vanishes in many parts of Great Britain and the Continent, particularly where the measles mortality is low, leaving a simple curve with a maximum in June and a minimum in September or October. (Reg.-Gen. Ann. Rept. for 1884. *See also* "Measles Epidemics, Major and Minor." *Transactions of the Epidemiological Society*, 1892–3.)

Measles epidemics are occasionally so malignant in type as to have a case-mortality of 30 per cent. or more, but in such instances neglect, improper treatment, or insanitary conditions have been largely responsible for the result. The epidemics now met with in Great Britain, though variable in severity of type, cause a case-mortality that rarely exceeds 5 per cent., and is often not more than 1 or 2 per cent. The fatal cases are, as a rule, due to pulmonary complications or diarrhœa rather than to the primary disease itself, the tendency to the one or the other complication being often fairly constant throughout an epidemic, but apparently independent of season (*Hirsch*). Convulsions are common, and, as sequelæ, retarded growth, deafness, and defective vision. Streptococcal infection (possibly from the mouth or naso-pharynx) is a frequent cause of measles mortality. Unlike scarlet fever, measles often disappears almost entirely from a district in the interval between epidemics. These intervals, however, are usually short, and few towns in England escape an epidemic for much longer than two or at most three years at a time. *Insular communities* such as Iceland and Faröe, with little communication with the outside world, remain free for an indefinite number of years (20-50) after the subsidence of an epidemic, until infection is introduced afresh. Then it appears with great severity, particularly among adults (Faröe Islands, 1781 and 1846; Fiji, 1875 and 1905; Shetlands, 1915). Occasionally measles, like smallpox, becomes "pandemic" and diffuses itself for a brief period over a large part of the globe.

Measles is said to have been inoculated by nasal mucus (*Bristowe*), with an incubation of seven or eight days. It has no known relation to soil. It does not appear to be transmitted by drinking-water, milk, or other food, or to have any connexion with diseases of lower animals. "Insanitary conditions"—notably overcrowding, exposure, and want of food—diminish greatly the chance of recovery, as was found in the outbreak among French troops in the siege of Paris, when 86 out of 215 (40 per cent.) died. Whether such conditions increase liability to attack is not known. The virus appears to be readily conveyed by the air, probably for considerable distances, but of this exact proof is wanting. Measles has not yet been isolated upon the large scale, so that the question of the possibility of aerial spread of infection from hospitals has not arisen. The disease is now notifiable.

From analogy it may be assumed that a specific measles microbe exists, but none has yet been satisfactorily demonstrated.

Infection is probably always acquired either by inhalation or direct contact. The **incubation period** is usually about 12 days, and is followed by the stage of invasion marked by pyrexia and catarrhal symptoms affecting chiefly the respiratory tract and the conjunctiva. The **rash** appears on the fourth day of illness, first on the forehead, then becoming general. It consists of dusky pink, slightly elevated spots, which increase for two or three days, and then slowly fade. Slight scurfy desquamation follows. Infection is given off by the breath and mucus from the onset of the first symptoms, and very possibly even during the stage of incubation. It is not clear how long this liability continues, nor whether the desquamated cuticle is infective, but the usual rule is to allow a quarantine of not less than three weeks. An attack is usually protective throughout life, and this is probably the main reason for the comparative immunity of adults, but well-authenticated instances of repeated attacks in the same person are far from infrequent (2–5 per cent.).

Comparing measles with scarlet fever, it is at once apparent that preventive measures are less likely to be successful against the former. Infection begins at least three days before the characteristic rash appears, and hence isolation is not adopted at a sufficiently early date to prevent the spread of the disease, so far as the household is concerned. The long incubation adds to the difficulty of quarantine.

Measles is still allowed to run its epidemic course practically unchecked by any serious attempt at isolation or disinfection, and it is, therefore, not surprising to find that it shows no signs of sharing in the reduction of mortality which is so conspicuous in respect of scarlet fever, enteric fever, and smallpox. The mortality per million in England and Wales has been thus: in 1851–60, 412; in 1861–70, 443; in 1871–80, 379; in 1881–90, 441; in 1891–1900, 414; and in 1901–10, 309. In 1911–12 a severe epidemic occurred. In 1915 there were 16,445 deaths in England and Wales from measles only (excluding deaths from complications), yielding a mortality of 462 per million.

It has been customary in the past to close elementary schools during measles epidemics. The results were, however, unsatisfactory. As a rule, measles spreads only in infant classes and only when 30–40 per cent. of the children are unprotected by previous attack. By means of "measles registers" it is possible to determine the measles history of a class, and though it is impracticable to prevent the introduction of the disease to the school, it is possible to prevent its spread by closure or by exclusion of unprotected children within 9–10 days of the first attendance of the initial case in an infectious state.

If the lowest age-limit of school attendance were fixed at 5 years the control of measles would become more practicable, as children of a susceptible age would not then be brought so largely into the sphere of infection. (*See also* p. 246.) The Public Health (Measles and German Measles) Regulations, 1915, require notification by parents or guardians to the **M.O.H.** (Art. V.) and by medical practitioners unless the case has been previously notified or is being treated in hospital. Careful supervision of cases and contacts, nursing, and hospital treatment are recommended.

GERMAN MEASLES

Rötheln, epidemic roseola, or German measles occasionally becomes epidemic among children, but causes very slight mortality. An outbreak in the New Forest in 1880 was, however, said to have been attended with a case-mortality of 3 per cent. After a latent period, often about 2½ weeks in length, slight general symptoms manifest themselves, and are followed immediately, or in a day or two, by an eruption of red, slightly elevated spots, variable in size and often confluent. They appear first on the face and forearms, increase and become more or less general in one or two days, and disappear before the end of a week. The symptoms have some resemblance to those of scarlet fever and measles, especially the latter. It is, however, an entirely distinct and independent disease, and not a "hybrid," as is popularly supposed. The disease is infectious, but never very actively so, and isolation for a fortnight is sufficient. Infection is probably given off by the breath, and acquired by inhalation. Second attacks do not appear to be common. Quarantine for contacts should extend to 23 days. The disease is now notifiable.

WHOOPING-COUGH

This disease has been recognized in Europe for 300 years, and has practically a world-wide distribution, although it appears to be on the whole less prevalent and less severe in hot countries. In London its average prevalence is greatest in March and April, least in September and October; but the seasonal curve of mortality varies greatly in different parts of Europe, and the New York curve has a second and greater maximum in September.

By far the greatest mortality occurs in the first year of life, and particularly in rural districts. Of the total deaths from pertussis, over 40 per cent. occur in the first year, nearly 75 per cent. under 2 years of age, and 96 per cent. under 5. At every age the mortality among females is greater than among males. There are no statistics sufficient to show the actual or relative incidence of attacks at different ages, but the vast majority occur in children, although age confers no complete exemption. Concurrent epidemics of measles and whooping-cough are frequent. Like measles, whooping-cough is a typically epidemic disease, and recurs at short but irregular intervals (usually two or three years) in outbreaks that affect a very large proportion of susceptible persons. The case-mortality is usually small, and probably seldom exceeds 5 per cent. The deaths are almost always due to bronchitis, pneumonia, convulsions, or other complications. Measles and whooping-cough together are, as a rule, responsible for more deaths of children than all the other infectious diseases put together.

Whooping-cough has not been shown to be transmissible by water, milk, or other food, or to affect lower animals, or to have any relation with telluric conditions. It is readily conveyed by fomites. Faulty hygienic conditions—especially overcrowding and exposure—increase the danger to life, but there is no proof that they increase susceptibility. The specific microbe has not been isolated, nor is the disease known to be inoculable.

Whooping-cough is, in all probability, always acquired by inhalation of the virus. The **incubation period** appears to be about a fortnight, but can rarely be fixed definitely owing to the very gradual onset of characteristic symptoms. Squire believed it to be less than a week. After a week or more of apparently ordinary nasal and bronchial catarrh, the characteristic paroxysmal cough sets in, and continues for a very variable period, which is rarely less than two weeks and may exceed two months.

Whooping-cough is certainly infectious in the preliminary catarrhal stage, and possibly even earlier than this. Isolation ought to be maintained until at least a week after the spasmodic cough has entirely disappeared. The infection is given off in the breath and sputa. Second attacks are very rare.

What has been said as to the prevention of measles applies in all respects to whooping-cough, and with even greater force. Owing to the absence of rash, and the insidious onset of symptoms, the disease is rarely detected until many days after it has reached the infectious stage.

MUMPS

Parotitis occurs in all parts of the world in brief but often intense epidemics, which cause little or no mortality. Cold and wet weather is the most favourable, and outbreaks usually occur in the winter and spring, often in concurrence with epidemics of measles, or sometimes scarlet fever. Mumps usually disappears entirely from a district at the end of the outbreak, and there is no appearance of periodicity in its return, which may be delayed for many years.

Nothing is known of its etiology beyond its extreme infectiousness by means of the breath. Second attacks are very rare. The characteristic symptoms, including swelling of the parotid and submaxillary glands, set in after an incubation of about three weeks (often 19 days), and the disease runs its course in about a fortnight more. Three weeks is sufficient for isolation, and four weeks for the quarantine of a person who has been exposed to infection.

SCARLET FEVER

Scarlet fever, or scarlatina, has been recognized in Europe for at least 550 years, and in England upwards of 200 years. It was long confounded with measles, and only in the nineteenth century was it definitely distinguished from diphtheria. It is most widely diffused in Northern and Western Europe, and in North America, but has failed to establish itself firmly in Africa, or any part of Asia except Asia Minor. Temperate and somewhat humid climates seem to be most favourable to it, but the evidence upon this point is conflicting. In England it is more prevalent in urban than in rural areas, mining districts and several of the large manufacturing towns being most affected of all. It is probable that the explanation of this is to be found in the greater facilities for receiving and transmitting infection from person to person. Scarlet fever has a well-marked relation to season. In England the mortality is at its minimum in March and April, and rises to a maximum in October, subject to irregularities if only small numbers or short periods are taken. In New York, however, the curve is almost reversed, the minimum being in September and the maximum in April. The number of attacks varies according to season in the same way as the mortality, but the seasonal range is greater in the attack-curve; apparently the attacks in early spring are, on the average, more numerous than those in autumn.

Age.[*] — Children under 1 year of age, and especially under 3 months, are comparatively rarely attacked, but the incidence rapidly increases and reaches its maximum in the fifth year of life. After that period it declines steadily year by year. About 45 per cent. of the attacks occur at ages under 5 years, 40 per cent. between 5 and 10 years, and 11 per cent. between 10 and 15 years. The average severity of attack, measured by the proportion of fatal cases, is greatest in infancy or in the second year, and diminishes as age increases, but there is an apparent increase in the severity of the (very few) cases that occur in adults after the fifteenth or twentieth year. The lessened liability with increasing age is greater than can be accounted for either by protection afforded by previous attacks, or by diminished exposure to infection.

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[*] The number of *deaths* from scarlet fever increases from birth to a maximum in the third year of life, and steadily declines afterwards; 90 per cent. of the deaths occur at ages under 10 years, and 65 per cent. under 5 years. Further details will be found in a paper on "Age, Sex, and Season in relation to Scarlet Fever," in the *Transactions of the Epidemiological Society* for 1887-8.

There is, therefore, a double gain in shielding a child from infection during the first few years of his life. Every year of escape after the fifth leaves him less and less susceptible, until finally he becomes almost immune; and secondly, if he should be attacked, every year that the attack is delayed reduces the danger to life, and also the risk of formidable complications that may become chronic and disabling, even if not immediately fatal.

Females are, upon the whole, more liable than males, but the attacks are somewhat less fatal, and hence up to 10 years of age the mortality is higher among males than among females. At ages above 10 the female deaths exceed the male, owing, no doubt, to the greater frequency of attack among women who have the charge of children. The death-rate from scarlet fever in England and Wales steadily declined from 971 per million in 1861–70 to 106 in 1901–10; and in 1911–14 it fell to 60. This reduction has been due not to lessened prevalence but to lessened severity and mildness of type.

Scarlet fever is for the most part an epidemic disease. Sometimes it will disappear entirely for years, or "sporadic" cases may occur without any serious general prevalence. In certain manufacturing towns, on the contrary, it may be said to be endemic, although subject to frequent epidemic outbursts.

Graves noted that scarlet fever was prevalent and malignant in Dublin from 1801 to 1804; during the next 27 years epidemics recurred at intervals, but the type was always mild and the mortality slight; in 1834 the disease reverted once more to the old malignant form; but in the next four decennia it was mild, with low mortality. Several instances are on record in which the type has suddenly changed during an epidemic from mild to severe, or vice versa. In some epidemics the case-mortality is as low as 3 per cent., or even less, while in others it may reach 30 per cent. As a rule the cases are more severe during the early part of an epidemic, and among children more fatal in town than in country, and more fatal to boys than to girls.

No adequate explanation has been offered of the causes that determine the rise and fall of scarlet-fever epidemics, and still less of the causes of the variations in type. Seasonal changes, especially meteorological, doubtless have an influence, but this is superadded upon the true epidemic wave. During the inter-epidemic intervals the proportion of susceptible persons increases, but as regards ages above 5 years the delay lessens the susceptibility, and it does not appear that the intensity of the outbreak bears any relation to the length of the previous interval.

Clinical features.—The **period of incubation** is usually three or four days, but it would appear that in exceptional cases it may be less than twenty-four hours, or as long as seven days. Some authorities believe the usual incubation period to be much longer, but Tonge-Smith's exact observations upon some cases which, owing to error in diagnosis, were exposed to infection during transit to hospital in an ambulance, afford strong proof of the accuracy of the estimate given above.

The **onset** in well-marked cases is sudden, with vomiting, rigors, headache, pyrexia, and sore throat as prominent symptoms. The red rash follows in about twenty-four hours. It is at first punctiform, but becomes diffuse. It is usually seen first about the neck and chest, but may spread over the whole body. The face generally remains clear of rash, though it may be flushed, leaving a pale area around the mouth. The rash occurs most markedly on points of pressure and at flexures. It increases for one or two days, and begins to decline in two or three days more. Desquamation begins as soon as the rash disappears, the chest being the first and the hands and feet the last parts to clear. True relapses occur in 1 or 2 per cent. of the cases, usually about a month after the onset.

Infection is given off from the first onset, and for a period that is seldom less than five weeks and not infrequently exceeds two months. It has been the practice to isolate until every trace of desquamation has disappeared from the feet, and still longer isolation may be necessary if any symptoms remain, such as discharges from the nose or ears, or albuminuria. But it is now not unusual to discharge cases from hospital after six weeks' detention if there are no nasal or aural discharges, regardless of desquamation, the later degrees of which are probably non-infectious.

The virus of scarlet fever retains its vitality for long periods, possibly years, under favourable conditions, and can be lodged in crevices, or carried in garments, etc.

Epidemiology.—By far the commonest mode of infection is from a previous case, either by contact, by proximity, or by means of infected articles. Whether the virus is usually inhaled or swallowed is less certain. Aerial convection for short distances—across a room, for example—may be assumed, but there is no proof of radiation of infection from scarlet-fever hospitals. Some authorities hold that at school ages notifications of scarlet fever, as of diphtheria, are lessened by holidays.

Nothing is definitely known as to any relation between soil and scarlet fever. There is no evidence that drinking-water can carry it, but milk certainly can, if infected from a human case of scarlet fever, and epidemics such as the Hendon outbreak suggest that the cow itself may not improbably be a source of infection. (*See* p. 143.)

It is at least doubtful whether "insanitary conditions" as to drainage, etc., have even a predisposing influence as regards this disease, but it seems probable that they may seriously affect the chances of recovery and promote septic complication.

It is often held that puerperal women are liable to acquire scarlet fever in a dangerous form, and that under such conditions its course may be modified and constitute a variety of puerperal fever. In the event of infection under such conditions scarlet fever may run a normal, and even mild, course.

Infection is given off by the breath and secretions from the nose, mouth, and throat; and most freely in the earlier and acute stages. How far the desquamated cuticle is infective is a matter of some doubt, direct experimental proof being wanting.

Bacteriology.—The pathogenic microbe of scarlet fever, according to Klein and Gordon, is a streptococcus (*Streptococcus scarlatinæ* or *conglomeratus*), which they isolated from the blood and nasal and tonsillar discharges of persons suffering from the disease. These observers have grown the streptococcus in broth, gelatin, agar, milk, and blood serum, in several of which media it gives a characteristic culture. It is pathogenic for mice and rabbits. Gordon believes that both *S. pyogenes* and *S. scarlatinæ* play a part in the causation of scarlet fever, but that *S. scarlatinæ* is the more important of the two, and occupies a position in the bacteriological kingdom between *S. pyogenes* and *B. diphtheriæ.* Baginsky, Sommerfeld, and Class have also isolated streptococci which they believe to be the cause of scarlet fever. Streptococci have been discovered in the nasal discharges of advanced convalescents, and in the throat secretions long after apparently complete recovery. This persistence may afford an explanation of the obscure "return cases" of scarlet fever. It should not, however, be forgotten that a streptococcus occurs in the saliva of healthy persons (*Gordon*). Mair believes he has isolated a specific diplococcus.

The **preventive measures** available are isolation and disinfection. Considerable difficulty arises from the long duration of the infectious stage, covering, as it almost invariably does, a period of at least four or five weeks after the patient has ceased to be ill. It is practically impossible, in a working-class household, to maintain the requisite seclusion, and the comparative freedom and better hygiene in hospital are conducive to the patient's welfare. Another source of difficulty is the occurrence of slight cases. There may be no noticeable symptoms whatever beyond sore throat, or slight desquamation, and yet any case, however slight, is capable of spreading infection. On the other hand, the short, and apparently non-infectious, incubation period, and the early appearance and distinctive characters of the rash and other symptoms, render this disease much more easy to deal with than measles or whooping-cough, if proper facilities are afforded. Schools are often instrumental in spreading infection, and it may be necessary to close them when epidemic prevalence is threatened. Scholars from infected households should be excluded for at least six weeks, and only readmitted upon a medical certificate, but a quarantine of two weeks is sufficient if the persons attacked have been removed to hospital and the premises disinfected (*see* p. 243). Special care is needed in guarding milk supplies from risk of direct or indirect infection from a case of scarlet fever, and there should be no hesitation in stopping the business if necessary. At the same time, it seems that boiling the milk removes all danger.

DIPHTHERIA

Although the term "diphtheria" was only introduced by Bretonneau in 1826, epidemics of malignant sore throat destroying life by suffocation, attacking children rather than adults, and sometimes leaving paralytic sequelæ, have been described from the earliest times. According to Hirsch, there is a tendency to cyclical *epidemic* or *pandemic* waves, lasting often for many years, and followed by long intervals of comparative quiescence. This long epidemic wave length is characteristic of diphtheria. Although no climate gives immunity, the tropics suffer less than cold and temperate climates. During last century France was one of the principal centres for diphtheria. In England localized epidemics occurred in 1815-25, after which the country was almost free from the disease until 1857, when it appeared as part of a general prevalence affecting almost the whole of Europe. The mortality increased during the next ten years, reaching 247 per million persons living. Since that time the disease has held its ground in England, and at the beginning of the last decade of last century showed a maximum prevalence, and a fatality of 272 per million. Its tendency recently has been that of a steady decline, due to improved and more rapid diagnosis and to the use of antitoxin. In 1916 there were 5,208 deaths from diphtheria in England and Wales, giving a death-rate of 0·14 per 1,000, against 0·50 per 1,000 in 1891–1900.

Season.—The curve of seasonal prevalence of diphtheria shows a relation to cold, the maximum mortality being reached in November to February, and the minimum in the summer. In New York the curve is similar. Records of epidemic prevalence show the same preference for the cold months (winter and spring), and many are associated with cold and wet weather. There are, however, many exceptions, in some of which heat has been regarded by local observers as inducing, and cold as arresting, the epidemic. In Great Britain atmospheric humidity is considered most favourable to the prevalence of diphtheria, but malignant epidemics have occurred in excessively dry weather in California, and Newsholme holds that the disease becomes epidemic in years or places in which the rainfall is deficient.

Diphtheria occurs upon high and low levels, and upon dry and moist soils; but Kelly observed a greater average prevalence upon damp soils, and this relation seems to hold good in many other parts of the country. A special incidence of diphtheria in damp houses has often been noted.

Locality.—Diphtheria was formerly, upon the average, more prevalent in rural than in urban districts; but in recent years it has shown a marked tendency to establish itself in towns, particularly affecting young children. Longstaff compared the statistics (1855–80) of the various registration counties in respect of their average density of population and average mortality from diphtheria, with the following result:—

Mean diphtheria mortality.	*Dense districts* (less than 1 acre per person).	*Medium districts* (1 to 2 acres per person).	*Sparse districts* (over 2 acres per person).
1855–60	0·123 per 1,000	0·182 per 1,000	0·248 per 1,000
1861–70	0·163 ,,	0·164 ,,	0·228 ,,
1871–80	0·114 ,,	0·125 ,,	0·132 ,,

The peculiarity of the distribution of diphtheria in regard to population suggests that its causes "should not be sought for primarily in any high development of civilization, such as sewers, but rather in some condition associated with a more primitive form of life" (*Longstaff*). A disease closely resembling diphtheria in many respects has often been observed to attack cats, pigeons, fowls, and horses during the prevalence of human diphtheria. This coincidence suggests that some part of the incidence upon rural districts may be due to infection from lower animals. Some of the symptoms of diphtheria have been produced in animals by inoculating them with diphtheritic material. Several minor outbreaks have been traced to infected cats from whose bodies the bacillus has been isolated.

Diphtheria frequently occurs in a purely sporadic form, no clue to any source of infection being discoverable, but all cases, whatever their origin, are highly infectious. It may be regarded as endemic in certain localities, sporadic cases bridging over the intervals between more or less frequent epidemics.

Air.—Several otherwise inexplicable outbreaks in secluded positions have been attributed to transmission of infection by wind for a distance of some miles. There is no a priori improbability in this explanation, but it seems clear that no such wind-convection can occur in those outbreaks that remain limited to certain streets or even houses in urban districts.

Water has been suspected of conveying infection, but no complete demonstration has been made out.

Milk, on the contrary, has been abundantly proved to convey the diphtheria poison (*see* pp. 137, 142). Many extensive outbreaks have been traced to this agency, and careful inquiry has brought to light a close relation in such cases between the quantity of milk consumed and the danger of attack. The milk may become infected by some person suffering from a slight attack of diphtheria, but we have now to bear in mind the possible occurrence of bovine diphtheria and of infection from the cow itself.

Drainage effluvia.—Diphtheria is more severe and more prevalent among persons exposed to foul gases from sewers or drains. The relation is, however, by no means direct. Houses with the worst forms of drainage defects may remain free from diphtheria for indefinite periods, and many cases of diphtheria occur in premises in which no defect can be found. The same may be said of other insanitary conditions, notably dampness of house, accumulations of manure and other filth in proximity to houses. All these ought probably to be regarded as predisposing causes only.

Age and sex.—The mortality is greater among females than among males at all ages between 3 and 45 years, and hence at all ages taken together. In both sexes the mortality increases from infancy to a maximum in the fourth year of life, and declines steadily thereafter, but there is a somewhat greater mortality (in proportion to the comparatively scanty surviving population) after the fiftieth year. Of the whole number of deaths ascribed to diphtheria, 53 per cent. occur at ages under 5 years, and 82 per cent. under 10 years.

Incubation.—"The most common period of incubation in diphtheria is from two to three days; less frequently the period is diminished to 24 hours or extended to four days; and the limit between an almost immediate operation of the infection and a delay of six or seven days practically covers the period of incubation for preventive purposes" (*Thorne-Thorne*). The early symptoms are often insidious, but as a rule the membrane is visible within a day or two of the onset, if not at first. In non-fatal cases the disease usually runs its course in two or three weeks. The case-mortality varies greatly in different epidemics, and there is little constancy even in the same epidemic. It is usually high in well-marked outbreaks: in pre-antitoxin days it was frequently 30 per cent., or more. It is now generally between 5 and 10 per cent. The protection conferred by an attack of diphtheria does not appear to be very great.

The mortality of hæmorrhagic diphtheria, which is confined to children (less than 5 per cent. of cases), is over 80 per cent. The cases which recover suffer from extensive paralysis. Treatment of these cases should consist in large doses of antitoxin associated with frequent administration of adrenalin.

Gresswell raised an important question in regard to those persons who have suffered from diphtheria in former years, and in whom acute inflammation of the tonsils is set up by change of weather or trifling exposure. He observed that among those associated with them at such times, diphtheria is apt to occur without discoverable cause; and suggested that the chronic morbid condition may really be a latent form of diphtheria, the occasional recrudescence of which becomes the starting-point for the spread of infection.

Slight cases, in which the symptoms are scarcely recognizable, are extremely difficult of diagnosis. During prevalence of diphtheria any sore throat should be regarded with suspicion, even if no membrane is visible and the constitutional symptoms are wanting. There is no necessary relation between the severity of attack in two cases of which one is infected from the other; the slighter case may impart fatal infection. In doubtful cases, where no membrane can be found, some assistance may be given by the knowledge of the existence of other cases of diphtheria, and paralytic sequelæ may ultimately clear up an obscure diagnosis. The breath and sputa are infectious from the first. Clothing, furniture, and even walls and floors, may retain the virus tenaciously.

Schools.—Schools afford, as Power observed in 1876, a favourable ground for the spread of diphtheria. There children at the most susceptible ages are brought together for some hours daily in close contact, often in a moist and impure atmosphere, with scanty ventilation; not infrequently such children use the same articles—towels, slates, pencils, etc.—and are brought into intimate contact with each other. Moreover, as Thorne-Thorne showed, a progressive development of virulence and infectiousness is brought about by the aggregation of slight (possibly unrecognizable) cases among susceptible children.

Among **preventive measures**, the first are notification of all forms, isolation, and disinfection. Doubtful cases and "carriers" should be supervised, and no children from infected households allowed to attend school. Supervision of "contacts" should be kept up for a fortnight, and if necessary prophylactic inoculation of antitoxin undertaken (500 units). Closure of schools may be advisable if many cases have occurred among the scholars, or if diphtheria is prevalent in the district, and especially if the school is the means of bringing children from infected villages into contact with others. (*See* p. 244.) Bacteriological examination should be instituted and throat swabs taken of all children in an affected class or group. Milk supplies found to be implicated in the spread of infection must be stopped at once, and most rigid precautions should be taken in regard to households connected with the milk trade. Lastly, insanitary conditions should be sought for and remedied.

Bacteriology.—It is now generally held that diphtheria is caused by a bacillus discovered by Klebs in 1883 and isolated by Löffler in the following year. It is a slender rod, straight or slightly curved, and beaded; there are also irregular and club-shaped forms. It differs in size according to its culture medium, but is generally 3 to 4 μ in length. Cobbett and Graham-Smith recognize five morphological types of diphtheria bacilli on young serum cultures: (1) oval bacilli, with an unstained septum; (2) long, faintly-stained, irregularly-beaded bacilli; (3) long, regularly-beaded bacilli — "streptococcal" forms; (4) segmented bacilli; and (5) uniformly-stained bacilli. All these forms are longer than the pseudo-diphtheria bacilli, more curved, and generally with clubbed ends. In the membrane which is its strictly local habitat in the body—indeed, with the exception of the secretions of the pharynx and larynx, and occasionally in lymph-glands and the spleen, the bacillus is found practically nowhere else in the body—it sometimes shows parallel grouping, lies on the surface of the exudation, and is separated from the mucous membrane by the fibrin. The bacillus possesses at least four negative characters: it has no spores and no power of motility; it does not liquefy gelatin, nor does it produce gas in cultures. It is stained with Löffler's methylene blue, and shows metachromatic granules and polar staining. Its favourable temperature is blood-heat, though it will grow at room temperature. It is aerobic. Löffler's medium is made by mixing three parts of ox-blood serum with one part of broth containing 1 per cent. of glucose, 1 per cent. of peptone, and ½ per cent. of common salt; the whole is coagulated. Upon this medium the Klebs-Löffler bacillus grows rapidly in 18–20 hours at 37° C., producing scattered, round, white colonies, becoming yellowish. The bacillus grows well in broth, but without producing either a pellicle or turbidity; it can grow on the ordinary media, though its growth on potato is not readily visible; on the white of egg it flourishes extremely well. In a moist condition, apart from the body, the bacillus has a low degree of resistance, but when dry can survive for long periods. The bacillus is secured from

Fig. 60.—Bacillus diphtheriæ from pure culture. × 900.

the throat by examination of a piece of the membrane or by a swab. Three examinations should be made before concluding that the throat is clear. About 30 per cent. of clinical cases of diphtheria offer no bacteriological evidence of infection. The bacillus may exist in the throat of infected persons for long periods, even several months, causing such persons, though apparently healthy, to be infectious. It may also be present in the throats of persons who have not suffered from the disease—"carriers"—and this fact doubtless furnishes the explanation of some sporadic cases and obscure outbreaks.

A *pseudo-diphtheria bacillus* described by Hoffmann has somewhat similar characters to the true Klebs-Löffler bacillus, and is frequently found in healthy throats, especially in children of the poorer classes. It differs from the true diphtheria bacillus in the following ways: it (*a*) is thicker in the middle than at the poles; (*b*) forms no acid in glucose culture media; (*c*) does not give Neisser's stain reaction; (*d*) differs in artificial culture; (*e*) does not agglutinate like *B. diphtheriæ*, and (*f*) possesses no pathogenic action. It is probably innocuous, but in practice it is the safest course to look with suspicion upon any throat harbouring pseudo-diphtheria bacilli.*

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* There are a number of other bacilli from which the true diphtheria bacillus must be differentiated. These include the *B. coryzæ segmentosus*, *B. xerosis*, and a number of "diphtheroid" bacilli, and organisms from nasal and aural discharges. There are certain chief characters by which the true diphtheria bacillus may be known: (*a*) The macroscopic and microscopic appearance of the growth on blood serum; (*b*) the behaviour of the bacillus to Löffler's blue, Gram's stain, and Neisser's stain for granules: (*c*) the acid reaction of a culture in alkaline broth containing 2 per cent. of dextrose after 48 hours at 37° C.°; (*d*) the invisible growth on potato; (*e*) the pathogenic test—1 c.c. of broth culture, 48 hours' growth at 37° C., injected subcutaneously into a 200–300 grm. guineapig, produced death generally in 48 hours, whilst post mortem hæmorrhagic necrosis and œdema are found locally, the internal organs are congested, the pleural, pericardial, and peritoneal fluids are increased, and the suprarenal capsules are enlarged and engorged with blood; (*f*) the virulence of the organism or its toxin is completely neutralized by a simultaneous dose of diphtheria antitoxin. For purposes of rapid diagnosis, (*a*) and (*b*) are usually accepted.

Antitoxin treatment of diphtheria.—Diphtheria antitoxin, prepared as described at p. 383, is injected subcutaneously between the crest of the ilium and the last rib. Strict asepsis must be observed, and the doses should be as large as practicable (2,000–5,000 units). Antitoxin is now very widely used in the treatment of diphtheria, and is increasingly used as a prophylactic in "contact" persons (300–500 units).

The following summary of the antitoxin treatment of all forms of diphtheria at the hospitals of the Metropolitan Asylums Board, 1895-1913, compared with the results obtained before the adoption of that treatment, affords striking evidence of the efficacy of diphtheria antitoxin:—

	Cases.	Deaths.	Mortality, per cent.
1890-3 (before antitoxin)	7,111	2,161	30·89
1894 (antitoxin occasionally used) . .	3,666	1,085	29·29
1895 . . .	3,635	820	22·85
1896 . . .	4,508	948	21·20
1897 . . .	5,673	987	17·69
1898 . . .	6,566	991	15·87
1899 . . .	8,676	1,182	13·95
1900 . . .	7,878	988	12·27
1901 . . .	7,622	849	11·15
1902 . . .	6,520	789	11·0
1903 . . .	5,072	504	9·7
1904 . . .	4,687	469	10·0
1905 . . .	4,148	347	8·3
1906 . . .	5,218	445	8·8
1907 . . .	5,744	544	9·6
1908 . . .	5,230	507	9·7
1909 . . .	4,893	432	9·4
1910 . . .	3,634	281	7·8
1911 . . .	5,084	428	8·4
1912 . . .	4,844	331	6·2
1913 . . .	5,076	330	6·2

Its value is particularly noticeable in children under 5 years of age, in whom there has been a steady proportionate decline in mortality.

At the Brook Hospital, MacCombie has kept records

showing the results of the antitoxin treatment, with special reference to the day of the disease on which treatment began, in order to illustrate the beneficial effect of early administration:—

MORTALITY PER CENT. IN CASES TREATED.

	1900	1901	1902	1903	1904	1905	1906	1907	1908[*]	1909
Cases treated on 1st day	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	3·0	0·0
,, ,, 2nd ,,	3·6	4·1	4·6	4·2	5·4	3·4	3·9	4·8	6·5	4·2
,, ,, 3rd ,,	6·7	14·9	10·5	17·6	10·6	6·3	8·7	13·3	10·6	7·0
,, ,, 4th ,,	14·9	12·4	19·8	16·0	19·5	11·0	18·5	9·7	12·9	11·5
,, ,, 5th ,, and after.	21·2	16·6	19·4	17·3	13·1	18·1	13·6	16·7	14·8	11·1

Similar reduction in mortality has taken place after using antitoxin in New York, Berlin, and Paris.

It is now customary not to discharge diphtheria patients from hospital until two consecutive bacteriological examinations of the fauces have proved negative. In the hospitals of the Metropolitan Asylums Board this results in an average length of residence in hospital of 50 days.

CROUP

This disease is credited with an annual death-rate of between 0·1 and 0·5 per 1,000 living. There can be no doubt that many deaths from diphtheria and laryngitis have been attributed to croup, and if, as some authorities still maintain, there is a true "croup"—that is, a non-infectious membranous laryngitis due mainly to wet and cold, and not followed by paralysis—it is of less frequent occurrence than the death returns would imply. The death-rate from croup is declining, and the decline is probably due to improved diagnosis. Outbreaks of diphtheria are commonly attended with cases of so-called "croup," which upon investigation prove to be diphtheritic.

The seasonal curve of deaths attributed rightly or wrongly to croup has its maximum in the cold months from December to March. It is much later than that of diphtheria, and approximates more closely to the laryngitis curve. In the distribution as regards age and sex a further difference from diphtheria is noticeable. Croup is more fatal to males than to females on the whole, the mortality among females being lower up to 15 years of age. The highest mortality in both sexes occurs in the second year of life. In all these respects "croup" is allied to laryngitis rather than diphtheria.

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[*] For all Metropolitan Asylums Board hospitals.

Erysipelas

Erysipelas occurs in all parts of the world, but more in temperate regions than elsewhere (*Hirsch*). In North America it has repeatedly taken the form of widespread and malignant epidemics; and in England and elsewhere virulent outbreaks often originated in former years in hospitals, especially in surgical wards where cleanliness, ventilation, air-space, drainage, and other sanitary essentials were neglected. At the present time outbreaks of this kind are rare, and erysipelas is chiefly met with in sporadic form. In its seasonal curve, and also in its local attachments and periods of recurrence, it is closely allied with scarlet fever and diphtheria, and still more closely with puerperal fever. It attacks males more than females, and kills more in early infancy than at any other period of life, although the mortality increases again after 25 years of age. After inoculation the incubation is usually from one to three days. It is not certain whether the disease is ever acquired except through some breach of continuity of skin or mucous membrane, but the occurrence of so-called "idiopathic" (non-traumatic) erysipelas points to this. The pathogenic microbe is a streptococcus, readily cultivated, and reproducing the disease upon subsequent inoculation.

Typhus Fever

Typhus has only comparatively recently been distinguished from enteric fever, but the two diseases are widely different in their etiology and epidemiology.

Typhus epidemics have been recorded in considerable numbers for several centuries past, more especially in times of war and famine, and were common in the seventeenth century and up to 1815. The only great epidemic in Europe since that time was in 1846-7. Ireland has been from earliest times one of the chief centres of the disease. Russia being another. Although for the most part limited to cold and temperate climates, typhus is by no means unknown in many hot countries, but usually at considerable elevation. The different habits of life, and especially the abundant ventilation, which prevail in warm countries may help to account for their comparative immunity, but as the effect of season remains marked, there is probably some further influence at work. In former times, epidemics of typhus frequently reached England, apparently by invasion from Ireland; but for many years past typhus has almost entirely disappeared from the southern and midland towns of England, although still occurring in the large towns of the north and of Scotland, especially those containing a large Irish population. The last general epidemic in Ireland was in 1862-4 (famine and distress).

Cases of typhus are most numerous in winter and spring, and in warm countries epidemics seldom occur at any other season. In countries in which typhus is common, however, the origin and course of epidemics are not checked by either extreme of temperature.

Telluric conditions are not known to have any influence.

The great predisposing causes of typhus are overcrowding, lack of ventilation, filth, debility, and privation. Wars and famines in former centuries were frequently followed by outbreaks of fever, among which typhus was prominent. "Gaol fever" (typhus) was common in English prisons up to the last century, owing to their filthy and overcrowded state. Better ventilation of vessels has rendered "ship fever" almost unknown, but accidental repetition of the old conditions, even in recent years, has led to fresh outbreaks of typhus. Typhus broke out in the Crimean War, 1854–5, in the Franco-German War, 1870, and in the European War (Balkans), 1915–16.

It is not clear that any race or class is especially susceptible, or the reverse, apart from the conditions under which they live; but, for the reasons already stated, the poorest classes suffer by far the most from typhus.

Age and sex.—The mortality from typhus increases from childhood to about 50 years of age, and then declines somewhat. It is greater among males, except, perhaps, in childhood. Handford finds that the susceptibility is greatest in the 10–15 years age period, but that the case-mortality, i.e. the proportion of deaths to attacks, is at its minimum in this period, and rapidly increases at later ages. Spear has called attention to the mildness of the symptoms in children, owing to which the initial attacks in an outbreak are liable to escape diagnosis.

The **incubation period** seems to be very variable, and, according to Murchison, may be only a few hours or as long as three weeks or more. It has been observed to be short in certain cases after exposure to the poison in a concentrated form. Perhaps twelve days may be taken as the most usual duration. The rash appears within a week after the onset, and, as a rule, on the fourth or fifth day. The disease generally terminates in death or convalescence about the end of the second week, and isolation may be terminated in ten days or a fortnight more. The mortality averages about 20 per cent., but varies with the age, condition, and surroundings of the patient, and with the epidemic.

Infection is given off by the breath, probably by the exhalations from the skin and mucous membranes, and possibly by the excreta. It is believed that the disease is largely spread by vermin, especially fleas and body-lice. According to Murchison, the infectivity is more active after the first week. The air immediately surrounding the patient appears to be infectious, but its virulence is rapidly lost by diffusion—a result that may be attributed to dilution, or desiccation. The poison clings readily and strongly to clothing and other fomites, but has not been shown to be conveyed by water, or by milk or other food. Doctors and nurses in typhus wards rarely escape for long unless protected by a previous attack. Second attacks are rare.

The powerful predisposing influence of overcrowding and want of ventilation may be explained by the facilities which they give for infection and for concentration of the poison, as well as their effect in rendering the individual more susceptible.

No pathogenic microbe is yet known, but it may safely be inferred from analogy that, without the presence of a specific virus, no intensity of the favouring conditions can originate an outbreak of typhus. It is, nevertheless, true that the disease often makes its appearance suddenly among overcrowded and filthy communities—on shipboard, for example—in instances where no previous case can be traced.

Typhus is essentially a preventable disease. Isolation of the patient, disinfection, and quarantine of persons exposed to infection will rarely fail to arrest a localized outbreak. Cleanliness and ventilation are auxiliaries of the first importance.

ENTERIC FEVER

Typhoid fever was differentiated from typhus in 1850 by Jenner. It is a disease of practically worldwide distribution, but is less prevalent in tropical regions than elsewhere. In England it is decreasing in prevalence, and in 1916 contributed not more than 0·03 to the average general death-rate. The death-rate in England and Wales in 1871–75 was 374 per million; in 1906–10 it was only 70, and it is still rapidly declining. The case-mortality is usually about 15 per cent.

Season.—In England the greatest prevalence occurs in October, and the minimum in May or June. The autumnal maximum is very general, but the exact position of the summit of the curve varies in different countries; in New York it occurs in September. High or low temperature of the air has in itself no clear relation to enteric prevalence, nor has the rainfall, but instances are recorded in which hot and dry summers were followed by high mortality from the disease, upon the occurrence of rain, and the reverse after cold and wet summers. It is probable, in view of the frequent relations between telluric conditions and enteric fever, that meteorological conditions act mainly by modifying the temperature and moisture of the soil, and that rainfall may either increase or diminish the chances of an outbreak according to the previous condition of the ground.

Soil.—Pollution of the earth by animal matter, especially if excrementitious in origin, is conducive to the endemic or epidemic prevalence of enteric fever. Pettenkofer and Buhl have traced a connexion between the movements of the ground-water and the occurrence of enteric-fever sickness and mortality in Munich, which has been confirmed by further observation in Berlin and other parts of Germany, and elsewhere. "The total of the cases of sickness and death from typhoid falls with the rise of the subsoil water, and rises with the fall of it; . . . the level reached by the disease is not in proportion, however, to the then level of the subsoil water, but only to the variation in it on each occasion; or, in other words, it is not the high or low level of the subsoil water that is decisive, but only the range of fluctuation" (*Hirsch*). This relation is so constant as to leave no room for doubt as to its reality and significance in the localities in question, but it does not appear to hold good in England, and Fodor has found exactly the reverse in Pesth. In many places where enteric fever occurs, the subsoil water is so deep and its movement so trifling that there is little probability of its producing any material effect. In Munich the soil is porous, the ground-water high, and, until recently, leaking cesspools are said to have been universal. As Buchanan has pointed out, the purity of water in wells is liable to be affected by changes in the level of the ground-water, and the readiness with which enteric fever is spread by means of specifically polluted water must not be lost sight of. The specific microbe is able to thrive in moist soil and upon dry linen for upwards of 70 days. (*Pfuhl*, *Firth.*)

Air does not appear to carry the poison of enteric fever under ordinary conditions even for the shortest distances; and the chances of infection by mere proximity to a patient are slight, though occasionally instances suggestive of this are met with. Infection from the sick to the healthy by direct or indirect contact is, of course, one of the commonest means of spreading the disease; water and milk being others.

Water.—While water polluted even with excremental filth has often been drunk for years by numbers of people with impunity so far as enteric fever is concerned, contamination with the excreta of a case of enteric fever has repeatedly been found to result in widespread outbreaks of the disease, the incidence of which in such instances exactly follows the distribution of the water, and affects only those persons who drink it. Such outbreaks rise suddenly to considerable proportions, but decline gradually. Corfield collected particulars of more than 50 water-borne epidemics of typhoid between 1864 and 1902. Some have arisen from specific pollution of shallow wells, as at Guildford in 1867, in the Uxbridge Rural District in 1882, at Hitchin in 1883, at Beverley in 1884, etc.; others from the pollution of deep wells. Thus an outbreak of enteric fever at Redhill and Caterham in 1879 was traced by Thorne-Thorne to pollution of one of the well-adits at the Caterham Waterworks by the excreta of a workman suffering from a mild attack of enteric fever, the organic impurity of the water, as shown by analysis, being extremely small. Another case of infection of a deep well was at Houghton-le-Spring, Durham, in 1889. The large outbreak at Worthing in 1893 (1,315 cases) was due to the consumption of water from a new heading which was contaminated by sewage. The water-borne poison is not dependent upon the organic matter in the water, but upon the specific pollution, which is not necessarily large in quantity.

Innumerable other instances are on record in which direct and obvious excretal contamination of wells, springs, streams, cisterns, reservoirs or water-mains has been followed by enteric outbreaks upon a large or small scale, according to the number of persons drinking the water. As illustrations may be mentioned the outbreaks at Caius College, Cambridge, in 1873, at King's Lynn and Maidstone in 1897, and at Lincoln in 1905. Buchanan found that, in the case of Caius College, the water in the main at Tree Court, which was chiefly affected, was contaminated by suction into it, during the periods of intermission of supply, of foul air from a soil-pipe, through a "weeping pipe" which supplied the trap on the waste-pipe of the safe-tray of a water-closet, the trap being liable to siphonage. The King's Lynn outbreaks (1892 and 1897) were traced to pollution of the sources of the water supply, namely, the river Gaywood, with typhoid excreta; and the same applies to the great outbreak at Maidstone (1,847 cases) in 1897, which was believed to have been caused by pollution of the springs by excremental matter from a colony of hop-pickers. In both these cases the filtration of the water as delivered was inefficient. The outbreak at Lincoln in 1905 included some 900 cases, and commenced towards the end of January. The river Witham and its tributaries, from which the supply was taken, were found polluted "by drainage from land highly cultivated, and occasionally manured with night soil." The effluent from a sewage farm discharged into the river above the intake. In the autumn of 1904, and in January, 1905, there were a number of cases of enteric fever in Lincoln, and, therefore, opportunity for the typhoid virus to gain access to the water supply, which, owing to increased acceleration due to heavy demands, was not effectually filtered in the filter-beds. The result was a water-borne outbreak of enteric fever, chiefly affecting households which did not boil their drinking-water. Many confirmatory observations have been made of places in which enteric fever, once endemic, has become rare coincidently with the substitution of a pure for an impure water supply. Thus at Millbank Prison, artesian well water was substituted for Thames water in 1854, and the previous endemic prevalence of enteric fever disappeared.

It is necessary to remember that the urine of the patient as well as the bowel discharges may contain the infective bacillus. Horton Smith showed in 1897 that the urine is infective in 25 per cent. of cases, and most frequently towards the end of the disease and during convalescence. In many recorded cases the typhoid bacillus has been found in the urine 3, 6, 8, 12, and even 18 months after convalescence. (*Semple, Greig, Aldridge.*) Klinger states that intermittent periods of bacillary infection appear to last in some cases over several years, and this may be found to explain the intermittent occurrence of typhoid cases in houses and streets over extended periods. Other observers have found bacilluria of this kind present in between 10 and 30 per cent. of the cases examined.

Food.—Milk was first recognized as a medium for the dissemination of enteric fever in 1857. Many instances have since been recorded, in England and other countries, the infection being sometimes traced to the use of polluted water for washing the cans or diluting the milk, sometimes to the milk being infected more or less directly by a person suffering from enteric fever (*see* p. 141). Oysters have on many occasions been suspected of conveying the infection of enteric fever (*see* p. 127). Fried fish (*Hamer*), ice-cream, watercress, and other foods have also carried enteric infection. When the disease is thus contracted it is characterized by multiple cases in houses, and an exceptional age-incidence.

Insanitation, drain effluvia, sewer gases, emanations from manure heaps and other filth accumulations, and the retention of excremental matter in the immediate vicinity of dwellings, are often regarded as directly causing enteric fever. That they are powerful predisposing causes is beyond doubt, and it may be supposed that persons exposed to their influence become more susceptible to the enteric poison. Alessi has shown experimentally that this is true of rats, rabbits, and guineapigs, after exposure to the effluvia from cesspools or excreta. The incidence of attack is heaviest upon households or districts in which drainage defects, or insanitary privies and earth closets, exist, although it is often difficult to dissociate their influence from that of impurity of soil and water. Buchanan has shown that in the large English towns improved drainage has greatly lowered the death-rate from enteric fever, and Newsholme states (1910) that "throughout England and Wales counties persisting in the use of conservancy methods of dealing with excremental matters, and not having adopted the water-carriage system, have excessive enteric fever in all instances in which industrial conditions imply considerable aggregations of population."

In connexion with infection contracted from filth or through food the agency of **flies** must not be forgotten (*see* p. 357). This was practically demonstrated in the Spanish-American War and the Boer War. They have also been shown to be an active agency in the spread of enteric and diarrhœa in urban communities. (*Niven.*)

Locality.—Enteric fever is more prevalent and more fatal, at all ages, in towns than in the country, and often fixes persistently upon one district, where the predisposing conditions mentioned elsewhere will usually be found to exist. In such districts newcomers are especially liable to attack; this has been observed on a large scale as regards soldiers newly arrived in India.

Age.—The Registrar-General's figures tend to show that the fatal incidence is less during the first 5 years of life than between 5 and 10 years. The registered mortality is low in infancy, high in the second to the fifteenth year, and then rises further to a maximum between 15 and 25 years, after which it falls permanently.

Sex.—More males than females die from enteric fever, but the mortality is greater among females from the fourth to the twentieth year of age. The susceptibility, according to the Registrar-General, is greater among males from about the fifth to about the twenty-fifth year, and greater among females at all other ages. The average severity of attack is somewhat greater among females; 18·8 per cent. of female cases end fatally, and 17·1 of male cases.

Typhoid "carriers."—Since Drigalski, in 1903, drew attention to the long saprophytic existence of the typhoid bacillus in the human intestine, much attention has been given to the subject of the typhoid "carrier" (i.e. the healthy person who yet carries infection in his body), and great numbers of cases have been recorded, particularly in Germany. Many of these cases have infected water, milk, and materials, as well as persons by direct infection. It is estimated that from 2·3 per cent. up to 32 per cent. of the total amount of typhoid fever is directly due to such carriage. Ledingham considers that the proportion of carriers in an ordinary population is about 3 or 4 per 1,000. He believes that the chronic carrier condition is more frequent in adult life than in youth, and in the female sex than in the male, and he recommends as measures of prevention (*a*) the early and fuller detection and isolation of carriers, (*b*) strict personal cleanliness, especially as regards the hands, of the carrier himself, and (*c*) the safe disposal of the infective excreta.* Many cases have been recorded which seem to indicate that infection may be retained in the body for many months and years.

Mode of infection.—The most frequent mode of infection is by contact or by the mouth, the virus either being contained in water, milk, or other food, or conveyed more directly by the unwashed hands after contact with infected matter. That the excreta and urine are infective is certain, and it is possible that infection is sometimes carried by the breath. Enteric patients are sometimes treated in hospitals side by side with other cases; but with scrupulous cleanliness, especially as regards the nurse's hands, and any clothing that may have become soiled, in however minute a degree, with the patient's discharges, it seems that, although nurses are not infrequently attacked, the infection has little tendency to spread to other patients. It is otherwise in crowded homes, and there can be no question that direct personal contagion has been the cause of not a few of the smaller outbreaks of the disease, and of many secondary cases in the larger epidemics (e.g. in the Lincoln outbreak of 1905).

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* For further particulars, *see* Thirty-Ninth Ann. Rep. L.G.B., 1909-10 (Medical Officer's Supplement), Cd. 5312, pp. 246-384. (*Ledingham.*)

The **incubation period** is variable, from two or three days to three or even four weeks, perhaps most usually 12 to 14 days. The insidious mode of onset renders exact determinations very difficult. The incubation is often short when the poison is introduced by water or milk. In some of Budd's cases it was only two or three days, at Guildford ten or eleven days, in the Caterham outbreak fourteen days. Jancken records an instance in which a body of soldiers, not otherwise exposed to infection, marched through two villages in which enteric fever was rife, and drank freely of water. Two days later 3 were attacked by enteric fever; then 7, 6, 0, 4, 5 in successive days, and 7 more within the fortnight—32 in all. The onset was sudden, but the course mild. Another section of the troops passed through the same villages without drinking, and escaped illness.

The duration of illness is usually about three to four weeks, but may be protracted by relapses. Second attacks are not uncommon.

The greatest care is needed to prevent all risk of contamination of milk supplies or water. The disposal of the excreta is a matter of great importance. They should be disinfected and disposed of at once. In the country it is customary to bury them away from houses or sources of water supply; in towns they are usually dealt with like other excreta, but where pail-closets are used enteric excreta may be separately collected and cremated. The urine, as we have seen, often contains the bacilli (in about 20 per cent. of cases).

Bacteriology.—In 1880–1 Eberth announced the discovery of the typhoid bacillus in cases of clinical enteric fever. In 1884 it was first cultivated outside the body by Gaffky. Since then other organisms have been held responsible for the causation of the disease. In 1885 the *B. coli communis* was recognized, and it was a matter of debate among bacteriologists as to how far these two organisms were the same species, and interchangeable. Bacteriologists now generally regard the Eberth-Gaffky bacillus (Fig. 61) as the specific cause of typhoid fever, though complete proof is still wanting. About 3 per cent. of typhoid cases are due to paratyphoid organisms (*Boycott*). Typhoid bacilli appear as rods, 2–4 μ long, 0·5 μ broad, having round ends. Sometimes threads are observable, being 10 μ in length. The bacilli differ in length from each other, but are approximately of the same thickness. There are no spores. Motility is marked, due to some five to twenty flagella of varying length. The flagella are both terminal and lateral, and are elastic and wavy.

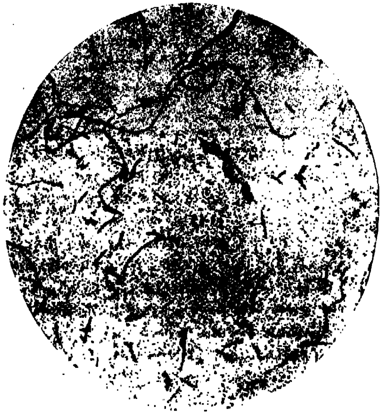

Fig. 61.—Bacillus typhosus from pure culture, showing long filamentous forms. × 900.

The organism may be isolated from the ulcerated Peyer's patches in the intestine, from the spleen, the mesenteric glands, and the urine. Owing to the mixture of bacteria found elsewhere, it is generally most readily isolated from the spleen. For this purpose the whole spleen is removed, and a portion of its capsule seared with a hot iron to destroy superficial organisms. With a sterilized knife a small cut is made into the substance of the organ, and by means of a sterilized platinum wire a little of the pulp is removed and traced over the surface of agar, on which growth occurs in twenty-four hours at 37° C. The bacillus grows on all the ordinary media. It is decolorized by Gram's method. The typhoid bacillus is capable of saprophytic existence in soil, dust, water, and milk, and may persist in the excreta for months. It may be conveyed by flies. It can survive in ordinary earth for two months, on sterilized linen for 60 days, on woollen cloth for 80 days, and in soils for upwards of 70 days.

Serum and vaccine.—Chantemesse has produced an antitoxic serum, which has yielded favourable results, particularly if administered early (dose 10–12 c.c.) A bactericidal antityphoid serum has also been introduced. Wright has prepared a vaccine from a virulent 24 hours' culture on agar, and after emulsification standardized to contain 1,000 million typhoid bacilli per c.c. They are killed by heating at 56–58° C. for 30 minutes, and ½ per cent. lysol is subsequently added. The dose is 500 or 1,000 millions of bacilli injected hypodermically in the flank. The blood of a person so inoculated responds well to Widal's reaction. The usual system is to inject two doses at an interval of ten days (½ and 1 cm. respectively), the patient being fit for work after forty-eight hours. Such inoculations have proved protective for cases exposed to infection, those in the incubation period, and unsuspected carriers and contacts. The prophylactic value of this inoculation was proved in India and America, and has been the chief cause of the remarkable immunity of soldiers in the European War, 1914–17. (In the British armies the mortality was 20 per cent. among uninoculated and 6 per cent. among inoculated.) The inoculation must be repeated about once a year. A mixed typhoid and paratyphoid vaccine is now used (*see* p. 444).

The typhoid bacillus agglutinates with serum from a typhoid patient, and this has been used as a bacteriological aid in diagnosis. It is known as *Widal's application of Gruber's reaction*, and is carried out in the following way: A few drops of blood are drawn from the lobe of the ear or finger of the patient; the serum (5 c.mm.), which exudes as the blood coagulates, is then diluted with neutral bouillon (95 c.mm.). A drop of this dilution is mixed on the slide with an equal quantity of a typhoid-broth cultivation of 18 to 24 hours' growth made from a virulent culture. Under the microscope it may be seen whether the reaction is positive or negative. If in the mixture of serum and of culture the bacilli become immotile and also become agglutinated, or grouped together in colonies, the reaction is positive. If, however, they remain, as they do in healthy blood serum, motile and scattered, the reaction is negative. The Widal reaction is obtainable in about 70 to 80 per cent. of the cases between the fourth and fourteenth day of the case and in 90 per cent. of the cases during the third and fourth weeks.

PARATYPHOID FEVER

Paratyphoid fever, first described by Achard in Paris, 1896, simulates ordinary enteric. The incubation period is 10–18 days. The onset is gradual, with headache, pains in the back and limbs, bronchitis, sore throat, and often a rose rash. The temperature rises in step-like form, reaching its maximum by the fifth or seventh day. The pulse is rapid. The majority of cases are mild and the death-rate is low. The clinical types of the disease are (*a*) the typhoid (the usual form), (*b*) the dysenteric, (*c*) the biliary—i.e. jaundice and cholecystitis, (*d*) the urinary and nephritic, (*e*) the rheumatic or arthritic, (*f*) the pulmonary—i.e. bronchitis, pneumonia and pleurisy, (*g*) the influenzal, and (*h*) the septicæmic. These terms designate the predominant characteristics. The lesions may be the same as in typhoid, or the intestine may escape or be acutely inflamed throughout, or the large intestine may be ulcerated. The disease is caused by *B. paratyphosus* A or B, which both thrive in the alimentary canal. The differences between this disease and enteric are that paratyphoid is (*a*) milder, (*b*) less fatal, (*c*) caused by organisms different from *B. typhosus;* and (*d*) Wright's vaccine does not protect. The paratyphoid bacilli are allied to the Gaertner and dysentery bacilli of Shiga and Flexner. Differential diagnosis is determinable by the agglutination test. Protection is secured by a mixed vaccine containing equal parts of *B. typhosus* and *B. paratyphosus* A and B. The principal channel of infection is infected "carriers." The prevention of paratyphoid fever depends on personal hygiene, sanitation, preventive inoculation, segregation of carriers, and early diagnosis.

Epidemic Diarrhœa[*]

This disease is returned as the cause of a death-rate that steadily averaged 0·9 per 1,000 from 1850 to 1880, and in 1909 was, for England and Wales, 0·28 per 1,000. In towns it is much higher (1 per 1,000) than in rural districts (0·52). In London, in 1914, it was 0·94, and 0·72 for England and Wales. In many cases diarrhœa is merely symptomatic, but the existence of an epidemic disease of which diarrhœa is the prominent manifestation is now recognized.

Density of population.—Epidemic diarrhœa is essentially a disease of towns, or, in more general terms, of crowded areas. The diarrhœa death-rate in 1891–1900 among children 0–5 years of age was 5·4; in urban counties it was 6·7 and in rural districts 2·6. The disease is ordinarily twice as fatal in urban as in rural counties, and more dangerous to boys than girls. In counties such as Dorset and Wilts the mortality (among children 0–5 years) in 1903 was below 2 per

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[*] Under this term are included all forms of zymotic diarrhœa and epidemic enteritis. The Royal College of Physicians (1900) laid down that "gastro-enteritis," "muco-enteritis," "gastric catarrh," and such synonyms of epidemic diarrhœa in medical certificates of death should be discarded. The College regarded epidemic diarrhœa as a general disease of a specific character in the same sense as enteric or other fevers, and therefore authorized the use of the terms "epidemic enteritis" or, if preferred, "zymotic enteritis" or "epidemic diarrhœa," to designate the disease in its various forms and degrees.

1,000, whereas in Warwickshire it was 8·8, in the East Riding of Yorkshire 8·9, and in Lancashire 9·13. In 1898–1902 the rate was 11·5 in urban districts and 5·0 in rural.

Urban conditions are favourable to the disease, chiefly for the following reasons :—

(*a*) **Density of buildings** upon an area increases the tendency to diarrhœa mortality, in addition to the density and overcrowding of population that usually, though not always, accompanies it.

(*b*) **Lack of ventilation and light** is conducive to diarrhœa mortality. Among the common conditions that are harmful in this way are narrow dark courts and streets, obstructive walls or buildings, back-to-back houses, overcrowding, and neglect of ventilation of rooms.

(*c*) **Domestic insanitation,** whether urban or rural, bears a definite relation to diarrhœa. Uncleanliness, unpaved and dirty yards, privies, refuse, manure-heaps, stables, all furnish occasion for the collection of infective material. Towns which have adopted the water-carriage system of sewerage have less diarrhœa than those which retain other methods of removal of excrement. Towns also which have the most effectual scavenging arrangements, including the methods of removal of house refuse, have the least epidemic diarrhœa.

(*d*) **Foul air** from sewers, cesspools, and filth accumulations of any kind promotes the incidence of diarrhœa. Smoke and mere chemical effluvia seem to be inoperative.

Soil.—Diarrhœa mortality is low in places built upon solid rock, high where the soil is loose and porous. Sand and deep mould are the worst, clay is far better. Organic pollution of the soil, whether vegetable or animal in origin, is a most potent factor, and occurs especially upon such sites as "made ground," pervious soils, town refuse, market gardens, or in soil polluted by leakage from drains or cesspools. Dampness of soil, accompanied by aeration, is the most favourable condition for diarrhœa, dryness or saturation being alike preventive.

Temperature.—High temperature of the air has long been observed to be associated with high diarrhœal mortality, and the reverse with low air-temperature, but Ballard has shown that the relation is indirect. The maximum mortality by no means necessarily coincides with the highest readings of the air-thermometer. The temperature of the soil, being a less sensitive indicator and more steady in its record, is on the whole a safer guide.

Ballard concluded that—

> "(*a*) The summer rise of diarrhœal mortality does not commence until the mean temperature recorded by the 4-foot earth-thermometer has attained somewhere about 56° F., no matter what may have been the temperature previously attained by the atmosphere or recorded by the 1-foot earth-thermometer.
>
> "(*b*) The maximum diarrhœal mortality of the year is usually attained in the week in which the temperature recorded by the 4-foot earth-thermometer attains its mean weekly maximum.
>
> "(*c*) The decline of the diarrhœal mortality . . . coincides with the decline of the temperature recorded by the 4-foot earth-thermometer, which temperature declines much more slowly than the atmospheric temperature or than that recorded by the 1-foot earth-thermometer.
>
> "(*d*) The influence of the atmospheric temperature, and of the temperature of the more superficial layers of the earth, . . . is little, if at all, apparent until the temperature of the 4-foot earth-thermometer has risen as stated above; then their influence is apparent, but it is a subsidiary one."

Tomkins found that epidemic diarrhœa did not occur in Leicester until the temperature of the 1-foot earth-thermometer reached 60° F.

Rainfall is operative by its cleansing effect upon the atmosphere, by laying dust, and by its reducing effect upon the temperature of the soil and the atmosphere. Diarrhœal mortality is greater in dry and less in wet seasons. Deficiency of rainfall and high atmospheric temperature are probably the two chief external conditions favourable to epidemic diarrhœa. Wind tends to reduce diarrhœa mortality, calm in the diarrhœal season promotes it.

It was upon the evidence concerning soil, temperature, and rainfall that Ballard, in 1887, based his "provisional hypothesis"—

That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life-processes of some micro-organism not yet isolated;

That the vital manifestations of such organism are dependent, amongst other things, perhaps principally, upon conditions of season and on the presence of dead organic matter, which is its pabulum;

That on occasion such micro-organism is capable of getting abroad from its primary habitat, the earth, and, having become air-borne, obtains opportunity for fastening on non-living organic material (especially food, whether inside or outside the body), and of using such organic material both as nidus and pabulum in undergoing various phases in its life-history;

That from food and from organic matter in certain soils it can manufacture a virulent chemical poison which is the material cause of epidemic diarrhœa.

Social position.—By far the greatest incidence is upon the poorest class, the artisan and lower labouring classes.

Food, water, and particularly milk, may become contaminated by exposure to dust or filth emanations, and thus cause diarrhœa. Flies are frequently the means of conveyance. Breast-fed children are remarkably exempt, and those partially breast-fed come next; the mortality is much higher among children artificially fed, and especially if fed by the bottle. On the whole there is evidence to show that infantile diarrhœa is usually a form of food poisoning.

Maternal neglect.—The mortality among illegitimate children is higher than that among legitimate children, from all causes, but the excess is greatest in regard to diarrhœa. The difference is most marked in years of low epidemicity, and tends to disappear in years of high diarrhœa mortality, but in the latter the average age of attack is earlier among illegitimate children. Occupation of mothers from home contributes to neglect and improper, irregular, and artificial feeding of infants.

Age.—Diarrhœa is fatal at both extremes of life. The first year of life, especially from the third to the ninth month, has by far the greatest mortality. In 1871–80 63 per cent. of the deaths attributed to diarrhœa were at ages under one year, 80 per cent. under two years. It was by far the most fatal of the infective diseases in infancy, and caused a mortality of over 25 per 1,000 births. In 1881–90 the mean mortality-rate showed further decline, and in 1891–1900 73 per cent. of the deaths from this disease were under one year and 86 under two. From infancy the mortality diminishes until about the twentieth year, after which it again increases until the end of life. The liability to attack seems to be greater in the second year than the first, and at all events is far greater in the first two years than in the third or later years. It is comparatively small in the first three months, and probably increases up to the end of the first or beginning of the second year. No age is exempt from attack, but only severe and acute attacks kill at ages between infancy and old age. Tomkins states that "infants and young children form only a small proportion of those attacked, although they furnish nearly the whole of the deaths."

Sex.—The mortality is greater among females from the third to about the forty-fifth year, but it is greater among males in infancy and old age. The liability to attack, however, is greater among males at all ages.

Season.—Fatal diarrhœa occurs at all seasons, but always increases greatly in summer. In London the mortality curve shows a slight rise throughout June, rapidly increasing in July, and reaching its maximum in the first week of August, after which it again falls steadily throughout September and October. During the rest of the year there is little variation. An outburst of epidemic diarrhœa occurs every year, but the date and intensity of the epidemic vary considerably from year to year, and according to locality. The relation to temperature and other atmospheric and telluric conditions has already been discussed. There is very frequently an alternation of years of high and low diarrhœal mortality, but a simple explanation of this is usually to be found in the meteorological records of the summer months, there being coincident alternation of hot, dry summers with others which are cool and wet.

Previous health affects the chances of recovery more than the liability to attack. The incubation is apparently very short, from a few hours to a day, or at most two days. Half the fatal cases terminate within a week, and the course is more rapid in the later periods of an epidemic (*Ballard*). Characteristic pathological changes are found in the kidneys as well as in the intestines—a fact that goes far to prove the specific character of epidemic diarrhœa. Pneumonia is common and fatty degeneration of the liver almost invariable.

Bacteriology. — In 1885 Escherich published his researches on *Bacillus coli communis*, and since that date many authorities have maintained that this organism is the causal agent of epidemic diarrhœa. Booker, on the other hand, as the result of investigation, concluded that many different varieties of bacteria are concerned in the etiology of the summer diarrhœas of children. He considered "streptococcus enteritidis" and *Proteus vulgaris* the most important. In 1895 Klein isolated an organism from the evacuations of patients suffering from an epidemic of diarrhœa at St. Bartholomew's Hospital, which he named *B. enteritidis sporogenes*,* and which he believes to be the cause of epidemic diarrhœa. *B. enteritidis sporogenes* is widely distributed, and occurs in normal and typhoid excreta, in sewage, manure, soil, dust, and milk. It has been frequently found in the dejecta of patients suffering from epidemic diarrhœa. It fulfils in a somewhat exceptional degree the requirements suggested by Ballard. But the same is true of *B. coli*, and the question is therefore *sub judice.*

Cause and prevention.—Whilst the bacterial rigin of diarrhœa remains obscure, it is certain that a) insanitary conditions, (*b*) soil and temperature, c) food, (*d*) fly conveyance of infection, and (*e*) caseo-case infection bear an important relation to the lisease. Different factors may become paramount at lifferent times or in different localities. The means f prevention are obvious—health visitation, appro-riate nursing, encouragement of breast-feeding of nfants, domestic cleanliness, protection of food, improved sanitation, destruction of flies, and, where practicable, isolation of the patient.

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* *B. enteritidis sporogenes* (Klein) is an anaerobic bacillus: 1·6–4·8 μ ong, and 0·8 μ broad; stains by Gram's method and ordinary stains; notile; spore formation present; large oval spores often situated near ne end of bacillus; grows well on gelatin and agar. In the former gas produced and the gelatin liquefies. It grows well in milk. After hirty-six hours of anaerobic incubation at 37° C. the surface is covered vith stringy, pinkish-white masses of coagulated casein enclosing a number of gas-bubbles. The main portion of the tube of milk contains a olourless thin, watery whey, with a few casein lumps here and there dhering to the sides of the tube. The whey has a smell of butyric acid, nd is acid in reaction. It contains many bacilli.

INFLUENZA

Influenza stands almost alone in its purely epidemic or pandemic occurrence, with little trace of endemic localization. Much confusion has arisen from the prevalent misapplication of the term influenza to severe catarrhs, infectious or otherwise. Many epidemics of true influenza have been observed during the last few centuries, spreading over a greater or lesser portion of the globe. Although there is clear indication of preference for lines of traffic, the progress of an epidemic is highly irregular. It appears simultaneously at widely separated points, often leaping over or avoiding entire countries, perhaps to appear in them later. It may be limited to particular towns or villages, sometimes even to a small section of the population in one part of a town. The advance is frequently rapid, but not more rapid than human traffic, and at other times its progress is slow and halting. The pandemic of 1889 was first heard of in Siberia, in May, and had spread to almost every part of Europe before the end of the year. It reached London late in December, and in the course of the next three months diffused itself over the whole of England.

The epidemic quickly reaches its maximum limits in a given centre, owing probably to its infectiousness and short incubation, and the susceptibility of the greater part of the population. It seldom remains longer than a few weeks in any locality, but may return in the course of the same pandemic. The interval between epidemics is irregular. Parsons states that major epidemics occurred in England in 1803, 1833, 1837–8, 1847–8, and minor epidemics about every three years. From 1860 onwards these practically ceased, until 1889, when a new series of epidemics began, each covering almost the whole country, at intervals of about a year; and these in ten years destroyed no fewer than 87,767 lives in England and Wales. In 1891–1900 the influenza mortality was 361 per million. During the decennium there were two epidemics—in 1895, when the death-rate rose to 423 per million; and in 1898–1900, when it was as high as 504 per million. There was another epidemic in 1918–19.

In the same district the type of the epidemic remains fairly constant as regards intensity, severity, and perhaps the tendency to one or other group of local symptoms or complications. There is, however, considerable variety in different centres during the progress of an epidemic, and the type may change in a given locality.

Season and weather.—Neither cold nor heat, nor any known meteorological condition, has been shown to have any effect in checking or promoting the spread of the disease. Intense outbreaks occur in the hottest and coldest seasons, in good, bad, and changeable weather, apparently indifferently. Each type of weather in turn has been alleged to cause epidemic prevalence, upon the strength of narrow observation confined frequently to one locality and one outbreak. It is, however, probable that conditions of climate, season, and weather may affect the severity of the epidemic, and especially the mortality from the respiratory complications that usually attend it.

Telluric conditions are apparently without influence. The disease attacks persons of all ages and both sexes, sometimes to the extent of quarter or even half the entire population. In general both incidence and severity of attack are less at ages below 20 years, and less among women than among men; though in some few localities and instances children, and especially school children, suffered more than adults. It would appear that influenza, like diphtheria, may become intensified by the aggregation of susceptible persons in a confined atmosphere. Whether it can spread through the air for long distances is doubtful. Many instances are on record in which it was apparently conveyed in that way to ships and lighthouses, but Parsons has shown that in some of these the isolation was not complete. On the whole, secluded persons and populations suffered least, the incidence being exceptionally heavy upon postal and railway officials, and others whose work brought them most into contact with the public.

The **period of incubation** appears to be short, from one to three days. The onset is sudden, with chills, elevation of temperature, severe pain in the eyes, head, and back, and tenderness of muscles, especially of the legs and back. Three principal forms of the disease are described, with affection respectively of the respiratory or the alimentary tract, or of the nervous system alone. Intense prostration and depression and rapid loss of weight are almost invariable. The symptoms usually abate in three or four days, but complications and sequelæ may protract the duration of illness indefinitely. The breath is in all probability infectious from the first.

The mortality from influenza is usually slight, except among persons already weakened by disease or predisposed to bronchitis or pneumonia. The increased death-rate which follows the appearance of influenza in a district is largely due to deaths attributed to respiratory diseases. The protection, if any, conferred by an attack is slight and evanescent, repeated attacks being common.

In 1892 Pfeiffer discovered a small bacillus in the bronchial mucus of patients suffering from influenza. It is aerobic, non-motile and non-resistant. It does not stain by Gram's method, and grows feebly on artificial media (preferably on blood-agar).

The ordinary preventive measures—notification, isolation, and disinfection—have not yet been employed on a large scale against influenza.

CEREBRO-SPINAL FEVER

Cerebro-spinal fever, known also as *epidemic cerebro-spinal meningitis* or spotted fever, is not rare in this country, and has recently caused serious mortality in New York and on the continent of Europe. In 1866-7 a severe epidemic in Ireland was marked by high mortality and hæmorrhagic rashes. Subsequently various small outbreaks took place up to the end of last century. From 1900-9 something of an epidemic wave of this disease occurred in Europe and the United States. A large number of cases occurred in Glasgow and Belfast. In 1913-17 very many cases were notified in England and Wales, and there is evidence of a new strain of infection from Canada. In Scotland between 1906-9 there were 2,600 deaths from cerebro-spinal fever.

The disease may be described as "an acute, epidemic disease, characterized by profound disturbance of the central nervous system, indicated at the onset chiefly by shivering, intense headache or vertigo, or both, and persistent vomiting; subsequently by delirium, often violent, alternating with somnolence or a state of apathy or stupor; an acutely painful condition with spasm—sometimes tetanoid—of certain groups of muscles, especially the posterior muscles of the neck, occasioning retraction of the head; and an increased sensitiveness of the surface of the body" (*Radcliffe*). Throughout the disease there is marked depression of the vital powers, and not infrequently collapse. In its course an eruption of vesicles, petechial or purpuric spots, or mottling of the skin, sometimes not unlike the rash of typhus, is apt to occur. If the disease tend to recovery, the symptoms gradually subside without any critical phenomena, and convalescence is protracted; if to a fatal termination death is almost invariably preceded by coma. After death the membranes of the brain and spinal cord are found engorged with blood, and an effusion of sero-purulent matter is often present in the meshes of the pia mater and beneath the arachnoid.

The **clinical manifestations** include the presence of Kernig's sign* and of *tache cérébrale.*† Among the other chief diagnostic symptoms are (*a*) intense headache, (*b*) vomiting, (*c*) stiff neck, (*d*) dilated or unequal pupils, (*e*) slow and irregular pulse, and (*f*) mental condition.

There are also milder or anomalous forms which render identification difficult, and which lead to cerebro-spinal fever being mistaken for other ailments of more common occurrence. In certain localized outbreaks in the Eastern Counties in 1890 it was generally mistaken for sunstroke or enteric fever; in Northamptonshire in 1890–1 it was diagnosed as pneumonia or sore throat;

Fig. 62.—Meningococcus from pure culture. × 1,200.

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* To obtain this sign the patient is placed so that the hip-joint is semiflexed, and while the hip-joint is retained in this position the knee-joint is extended passively. A contraction of the hamstrings then sets in, which causes resistance to the extension.

† A congested streak produced by drawing the finger-nail gently over the patient's thigh, abdomen, or face. In cases of meningitis this appears earlier (within 30 seconds), lasts longer (8, 10, or 15 minutes), and is broader and of deeper colour than in healthy persons.

and in Irthlingborough in 1905 many of the persons attacked were regarded as suffering from influenza. When death ensues rapidly the disease has been mistaken for typhus, tetanus, or malignant measles.

Cerebro-spinal fluid withdrawn from the lower part of the spinal canal by lumbar puncture should be examined for the presence of the *Diplococcus meningitidis intracellularis* of Weichselbaum, the meningococcus (Fig. 62), now regarded as the specific cause of the disease. The organism occurs in pairs in pus cells and nasal mucus. It grows on blood- or ascitic agar at 37° C. (not below 25° C.) and is Gram-negative.

Mode of spread.—Cerebro-spinal fever has a much more restricted direct infectivity than characterizes a disease like smallpox. In most outbreaks only one member of the invaded family develops the disease, though exceptions are not uncommon. The meningococcus is found in the mucous secretion of the naso-pharynx in a considerable proportion of those suffering from the disease, especially in its earlier stages, and also in some apparently healthy contacts, by whom it may be conveyed.

Outbreaks of cerebro-spinal fever are usually associated with overcrowding of civil or military populations, lack of cleanliness and ventilation, and frequently with inclement conditions of weather. In such circumstances it appears likely that the resistance to infection is lowered, the opportunities for infection are increased, and that possibly the virulence of the meningococcus is exalted. Excessive fatigue in some outbreaks has appeared to predispose to infection. The chief incidence in the civil population is upon children and occurs in the spring of the year, January to May.

Administrative action. 1. **Notification of the disease.**—In 1912 an Order of the L.G.B. made cerebro-spinal fever and poliomyelitis compulsorily notifiable throughout England and Wales.

2. **Bacteriological aids to diagnosis.**—Examination by a competent bacteriologist of cerebro-spinal fluid withdrawn from the spinal canal by lumbar puncture will determine the presence or absence of the meningococcus.

3. **Isolation of the patient.**—The isolation of the patient should be secured, and skilled nursing should be provided. It is important to have a separate room or ward available at the local isolation hospital for patients suffering from this disease. Such patients often do not bear removal to a distant hospital. Contacts should be kept under supervision for three weeks, and should use a suitable nasal spray (e.g. potassium permanganate 1-1,000), or insufflation, gargle, or mouth-wash.

4. **Disinfection.**—During the patient's illness precautions in regard to throat secretions, handkerchiefs, towels, feeding utensils, etc., should be taken, similar to those for diphtheria. When the sick-room is vacated it should be thoroughly disinfected and cleansed; and the patient's clothing, pillows, bedclothes and bedding should be subjected to disinfection by steam. Steam atomizers may be used.

5. **Investigation of sources of infection.**—Special attention should be directed to cases of sore throat, headaches, pains in back and limbs, etc., suggesting "influenza." The important share borne by healthy "carriers" as agents of infection should be kept in mind. Many "healthy" persons act as carriers of the meningococcus, which may also remain in the naso-pharynx of convalescents for many weeks.

The infectivity or otherwise of contacts can be determined by taking swabs from the upper part of the naso-pharynx.[*] Swabs from the fauces are of small value. It is important to avoid contamination of the swab by the bacteria of the mouth and fauces. This has been effected by using a swab mounted on a long rod, curved at its distal end, and protected by a metal cannula. The swab should not be extruded until the end of the cannula has passed behind the uvula, and should be withdrawn into the cannula immediately after careful contact has been made with the mucous membrane of the naso-pharynx. As the meningococcus does not live long in the swab, it is desirable that Petri dishes containing suitable media should be obtained direct from a laboratory and inoculated directly the swab has been taken. The first Petri dish may become overgrown with extraneous organisms, and it is therefore desirable to use two dishes, the second being inoculated from the first by means of a sterile glass rod or other sterile implement. Antimeningococcic serum should be injected intraspinally as early as possible.

ACUTE POLIOMYELITIS

This infectious and communicable disease has long been known as *infantile paralysis*, a form of sporadic paralysis occurring among children of 1–5 years, and also among adults. The most extensive epidemics have occurred in Scandinavia, Germany, and America. From 1900 and onwards various outbreaks occurred in England and Wales, and in 1911–15 upwards of 2,500 cases were reported.

The virus attacks the nervous system, causing inflammation of the grey matter of the spinal cord, especially of its anterior cornua. Microscopically the characteristic lesions found are hyperæmia, a well-marked exudation of lymphocytes around the blood-vessels, and degeneration of the large motor cells in the anterior horns. Less often the whole cord, grey and white matter, may become involved and a transverse myelitis result. In some cases the brain may be primarily or secondarily affected. Hence the suggested name of polio-encephalo-myelitis. The meninges also may become implicated in the morbid process.

Clinical. — Clinically the disease takes four forms: (1) spinal, (2) cerebral, (3) bulbar, and (4) abortive. Preceding paralysis, the symptoms are those of an infectious disease. They vary with the localization of the virus. There is no characteristic skin eruption. Usually an initial febrile attack occurs, the temperature seldom rising above 102–3° F.; commonly there are malaise and drowsiness, accompanied by headache and occasionally by vomiting; there may be nasal and pharyngeal catarrh. The patient is fretful, and objects to being moved. Rigidity of the muscles of the neck and spine frequently occurs, and the head may be retracted; there may be pain or tenderness over the spine. Kernig's sign (p. 455) is often present. Plantar, patellar, or abdominal reflexes are commonly absent; the patellar reflex may, however, be exaggerated in the early stage. Paralysis, mainly of the flaccid type, supervenes, affecting one or more groups of muscles, especially of the limbs, but may involve any part of the muscular system.

This is the common form of the disease, but occasionally a child may go to bed apparently well and be found in the morning to be suffering from paralysis.

There is little difficulty in recognizing the above forms of the disease. But, apart from the symptoms mentioned, or in addition to them, there may be symptoms caused by implication of the medulla, brain, meninges, or special nerves; and in such cases, especially when the meninges are implicated, confusion in the differential diagnosis between poliomyelitis and cerebro-spinal fever is apt to occur. The meningeal type may also be confused with tuberculous meningitis or septic meningitis. The symptoms of poliomyelitis, before the onset of paralysis, have frequently been attributed to influenza, sunstroke, enteric fever, food poisoning, and a number of other diseases.

The fatality of poliomyelitis has varied within wide limits in the epidemics of the last few years. Commonly 10 to 12 per cent. of the attacks prove fatal. Over half the patients who survive an attack of poliomyelitis are crippled for life. The disease is most prevalent in late summer and least prevalent in the winter months. It appears to have no special relationship to social or sanitary conditions; and, so far, has been oftener recognized in sparsely populated districts than in large towns. The disease is transmitted from person to person, and by a healthy "carrier." In some instances it has developed after only slight or temporary contact with a patient suffering from poliomyelitis, and multiple attacks in households are not uncommon. In other instances children have been known to sleep in the same bed with a patient and escape infection.

In monkeys experimentally inoculated with the disease the incubation period is stated to vary from three to forty-six days, the general period being about eleven days. The incubation period when the disease is naturally acquired by man is four to eight days, though shorter and much longer periods are recorded.

Pathology.—The virus can attack rabbits as well as monkeys (Flexner), and both escapes from and enters the body through the nasal mucous membrane. It can enter and leave also through the digestive system. Its spread in the body is chiefly by the lymphatics. It retains its virulence in a dry state, in dust, and on fomites. Healthy human carriers are numerous; their naso-pharyngeal and intestinal secretions contain the virus. Insects (particularly flies) may be potential carriers. The virus has not been cultivated outside the body with absolute certainty. Inside the body it is found in the brain, spinal cord, and mesenteric glands, and in the mucous membrane and secretions of the nose and throat, the stomach, and intestines (Flexner). The micro-organism is not present in the blood or in the spinal fluid, which, however, may contain excess of lymphocytes. Its virulence differs widely even in the same epidemic, and the susceptibility of human beings also varies greatly. Immunity is conferred by one attack.

Preventive measures.—Poliomyelitis is notifiable. Isolation should be provided and is particularly important. Precautionary measures should be taken in all suspected cases. As it has been shown experimentally that the virus is present in the nasal mucous membrane, an antiseptic solution should be applied by means of a spray to the throats and nasal passages, not only of the patients, but of all persons brought into contact with them. The virus can be killed experimentally by a 1-per-cent. solution of peroxide of hydrogen, or by a solution of permanganate of potassium 1 in 500. All discharges from the patient as well as all articles which may be soiled by such discharges should be immediately disinfected. No child should be allowed to attend school from an infected family. Kissing, coughing, sneezing, and spitting tend to spread the disease.

EPIDEMIC PNEUMONIA

Pneumonia occasionally occurs in an epidemic form, and in many instances has shown infectious properties without attaining epidemic proportions. Epidemic pneumonia is, with few exceptions, of the "croupous" or "fibrinous" form, but it is not certain that all cases of sporadic croupous pneumonia are due to infection, or that infectious pneumonia is always caused by the same virus. Infectious pneumonia is very often limited to the upper lobe, and often accompanied by pleurisy or empyema. Gastric symptoms, diarrhœa, and jaundice are common, and prostration and cerebral symptoms are frequently intense, out of proportion to the physical signs of pneumonia. The latter may be delayed for several days after the onset.

Numbers of epidemics have been described in England and various other parts of Europe during the last two centuries. Although more frequent in temperate climates, many are recorded in the West Indies, Mexico, Peru, and India. Nearly all occur in winter or spring, and the seasonal curve of epidemic prevalence coincides pretty closely with that of pneumonia mortality, which has its maximum in December, and is high from November to April. Hence the prevalence of pneumonia—epidemic or otherwise—is associated with the colder months. A closer analysis shows that in each climate the greatest prevalence of pneumonia occurs at the season of most rapid and sudden changes of temperature, be it winter or spring (*Hirsch*), and there is evidence tending to show that the prevalence varies in some measure with the changes of temperature. Epidemics occurring at unusual seasons have in many cases been associated with unusual meteorological conditions of the same kind.

The popular belief in "**chill**" as an exciting cause of pneumonia cannot be entertained as regards infectious pneumonia, in spite of the strength of the evidence which connects pneumonia outbreaks with the weather conditions in which "chill" is believed to be most liable to occur. Exposure to sudden changes of temperature or extreme cold may increase the activity of infection or the susceptibility of the individual, but nothing more. If, however, there is a non-infectious and non-specific croupous pneumonia, the question of "chill" may be argued upon different lines. It is said that croupous pneumonia has been produced by injecting irritants into the lungs of dogs, by mechanical injury to lung tissue, by experimentally injuring parts of the nervous system, and by various other mechanical means, which may be admitted as establishing some sort of prima-facie possibility of like effect from sudden change of temperature, especially as the whole mortality attributed to pneumonia (and not merely that part which is already recognized as due to an infectious form of the disease) reaches its maximum at times of greatest liability to "chill." On the other hand, attempts to produce pneumonia by exposing animals to sudden alternations of temperature have uniformly ended in failure, and even traumatic pneumonia may conceivably be dependent upon the co-operation of specific microbes accidentally gaining access to the injured tissue.

There are now on record many instances of outbreaks of pneumonia which remain limited to a single household or a small circle, but in which nevertheless the evidence points strongly to infection.

Nothing conclusive has been established as regards the influence of rainfall or telluric conditions upon pneumonia, although it has been asserted that absence of rain (dry cold) and low level of subsoil water are favourable conditions.

Sex.—Males are far more liable to pneumonia than females, but the attacks are usually less severe and less fatal. In the Middlesbrough epidemic of 1888 Ballard found that the female case-mortality only exceeded the male at ages above 65 years. Both the liability to attack and the average case-mortality increase greatly as age advances. In childhood and old age the mortality is highest, and urban death-rates are usually in excess of rural.

Predisposing causes.—All depressing conditions predispose to attack during epidemic prevalence, among them fatigue, anxiety, poverty, and debility from any cause. Insanitary conditions, especially filth, overcrowding, and want of ventilation, act apparently as powerful but not indispensable predisposing causes. Effluvia from graveyards have also been held responsible for outbreaks. Repeated outbreaks have sometimes been observed in the same buildings, especially barracks and prisons. Negroes are especially susceptible to pneumonia, even in their native climate.

Bacteriology. — Friedländer's oval, capsulated pneumobacillus is found in large numbers in the affected lungs, and in the blood and sputa in croupous pneumonia (but not in acute catarrhal pneumonia or septic pneumonias). It was found in abundance in the substance of the floors and ceilings of rooms in a prison at Amberg where repeated outbreaks of pneumonia had occurred for many years (*Emmerich*). Pneumonia has been produced in rabbits by the injection of cultivations. On the other hand, these results have been disputed, and the true pathogenic microbe asserted to be Fränkel's small, oval, capsulated diplococcus, which is non-motile, non-liquefying, and aerobic. It is difficult to cultivate, and rapidly loses virulence. It is stained by Gram's method. It is by far the most frequently-present organism in croupous pneumonia, and may be present in other diseases—suppuration, otitis media, ulcerative endocarditis, and meningitis.

The widespread and fatal epidemic that occurred at Middlesbrough in 1888 was investigated by Ballard. Out of 1,633 cases in a population of 97,000, 369 ended fatally, the case-mortality being 21 per cent. The poorer classes were attacked more than the wealthy, and cases were exceptionally numerous and severe in the workhouse, where the drainage was very faulty. The workhouse children suffered six times, but adults only one and a half times, as much as the corresponding class outside. Exposure and fatigue seem to have acted as predisposing causes, and many apparent instances were recorded of direct infection from contact with a sick person. The progress of the epidemic seemed to be arrested by heavy rains, and to be most rapid during rainless periods. Klein found neither Friedländer's nor Fränkel's organism, but large numbers of short bacilli, which he inoculated into mice, causing pneumonia; further inoculations from such mice imparted the same disease to other mice. Samples of bacon were purchased in the infected districts, and it was found that of mice fed upon this bacon a large proportion became ill with the same symptoms as those mentioned above.

The incubation appears to be short, frequently about five to seven days. The onset is sudden, and usually marked by rigors and severe constitutional symptoms, the signs of pneumonia being often delayed for three or four days. The fifth day is often fatal;

and, on the other hand, crisis often occurs on or about the fifth, seventh, or ninth day, but sometimes the course, even in non-fatal cases, is severe and protracted, the symptoms being of a "typhoid" character. Both the breath and the sputa may be assumed to be infective. The mortality varies considerably, but is usually high, especially in elderly persons and in the outbreaks limited to a narrow circle. In some epidemics, however, it has been as low as 5 per cent. Epidemics of pneumonia often occur coincidently with outbreaks of other diseases, and especially enteric fever.

TUBERCULOSIS

Tuberculosis is a specific and infective disease common to man and the lower animals. The principal form in which it affects man is pulmonary tuberculosis or *phthisis*, but all parts of the body are liable to be invaded. *Tuberculous meningitis* is not sufficiently distinguished in death-returns from other diseases that are attended with somewhat similar symptoms; "*tabes mesenterica*" (tuberculosis of peritoneum, intestine, and mesenteric glands) includes a large annual number of deaths among children from wasting diseases, of which no exact diagnosis has been made. Fourthly, there is *tuberculosis of bones and joints*; and lastly, *disseminated tuberculosis.*

Phthisis, "consumption," or pulmonary tuberculosis, is largely dependent upon known and remediable conditions, and improved hygiene has led to a steady decline in mortality from this cause. Nevertheless it still ranks among the most fatal diseases, especially during adult life, and as recently as the decennial period 1891–1900 it was the recorded cause of one-twelfth of the whole mortality in England, and of about 30 per cent. of the deaths at ages between 20 and 45.

Its **geographical distribution** is almost world-wide. Neither hot nor cold climates are exempt, but humidity, especially if the daily range of temperature is high, is frequently associated with prevalence of phthisis. Cold, and especially Arctic, countries suffer comparatively little as a rule, and the exceptions are mostly explicable by social conditions involving overcrowding and the absence of ventilation. Other things being equal, elevated and mountainous regions are less affected than lowlands, owing, it is believed, to the dryness and purity of the air and soil, and the fuller and deeper respiratory movements. A general relation between dampness of soil and prevalence of phthisis has been affirmed by Buchanan* in England and Bowditch in America. Considerable and early reduction in phthisis mortality has, in many instances, followed artificial drainage of damp localities.

Towns suffer more than rural districts, and there is a close relation between density of population and phthisis mortality, due to the co-operation of several causes, chief among which are overcrowding, poverty, and stagnation and impurity of air. The heaviest incidence is upon the poorer classes, and especially those living in narrow streets, alleys and courts, and in back-to-back houses. Conditions inside the houses such as darkness, overcrowding, and want of ventilation are even more potent, and repeated experience in barracks, workhouses, prisons, and other public institutions, as well as in ships, has shown that with improved ventilation and ampler air-space the mortality from phthisis is greatly reduced. Among nomadic races the disease is rare.

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* The mortality statistics of the decennium 1851-60, for Surrey, Kent, and Sussex, showed that there was less phthisis among populations living on pervious soils than among those living on impervious soils; less on high-lying pervious soils than on low-lying pervious soils; less on sloping impervious soils than on flat impervious soils. Buchanan also found a general agreement in phthisis mortality between districts that have common geological and topographical features of a nature to affect the water-holding quality of the soil—an agreement not observed in districts differently circumstanced in such respects; and further, a general parallelism between the degree of wetness of soil and the degree of phthisis incidence.

Predisposing conditions. — Many occupations tend to induce phthisis (potmen, cutlers, tin, lead, and copper miners, bookbinders, printers, hairdressers, etc.), and especially those industries which are carried on in overcrowded, hot, moist workrooms, or which charge the air with mineral or organic dust of an irritating kind. Exposure to rapid alternations of temperature is very injurious. Greenhow attached much importance to a stooping or cramped posture at work, as predisposing to phthisis.

Among other predisposing conditions, intemperance and debilitating causes of all kinds are important. Brouardel considers that "alcoholism is the most potent factor in propagating tuberculosis," and he quotes Baudran as showing that the deaths from tuberculosis per 10,000 rise in proportion to the annual consumption of litres of alcohol per head. In this country the Registrar-General has shown that more than one-quarter of the deaths of innkeepers and their servants in London result from phthisis; more than one-third of the deaths of public-house servants, barmen, and potmen in London are due to phthisis and the mortality from this disease among London innkeepers and their servants is more than twice as great as that among all occupied males, and the mortality amongst the servants alone is more than three times as great. No doubt some of this mortality is due to inhalation of tuberculous dust from dried sputum. Then there is the lowering effect of malnutrition and previous disease. Attacks of pleurisy, bronchitis, or pneumonia increase the liability to phthisis, and also many forms of specific fever (measles, whooping-cough, and enteric fever), and other diseases, such as diabetes and insanity. The low phthisis mortality among fishermen, agricultural labourers, and others following essentially out-door employments, seems to indicate that exposure to weather has been overrated as a predisposing cause, for this condition in a great measure implies abundance of fresh air.

No race is exempt, but among Jews phthisis appears to be rare, and this comparative immunity has been partly attributed to the care that is taken in the selection of animals slaughtered for food. Natives of hot countries migrating to cold, damp climates are very prone to phthisis.

The tendency to phthisis may be inherited, in the form of constitutional weakness, or of a narrow, contracted chest. Whether heredity can do more than strongly predispose to the disease is very doubtful. Tubercle has in rare instances been found in children within a few days of birth, and even in the fœtus. Various observers have obtained evidence of parental phthisis in from 15 to 30 per cent. of the cases coming under their notice, but this proportion is scarcely sufficient to establish the proof of heredity. A family history of phthisis is obtainable in 50 per cent. of hospital cases of this nature.

Mortality.—Rightly or wrongly, a large but decreasing number of deaths of young children under 5 years of age is attributed to phthisis. The annual mortality per million living at ages under 5 years was 973 in 1861–70, 770 in 1871–80, 535 in 1881–90, and 413 in 1891–1900. From 5 to 10 years the mortality is at a minimum, and then rises steadily to its maximum at ages between 35 and 50, after which it declines again as age advances. The death-rate in England and Wales from all forms of tuberculosis fell from 1,902 per million in 1900 to 1,515 in 1915 (in which year 54,295 persons died of the disease).

The phthisis mortality has fallen during the past half-century by more than 50 per cent. at all ages and by about 70 per cent. at ages 0–25. From that age onwards the fall has been considerably less marked, and has been more pronounced in females than in males. Generally speaking, the decline since 1861 has been due to improved sanitation, nutrition, and social conditions, combined with increased knowledge as to infection and the influence of institutional and sanatorium segregation of infectious cases.

Sex.—The influence of sex is very marked, but is to be explained for the most part by differences of surroundings rather than by variation in natural susceptibility. In proportion to their numbers males suffer a higher phthisis mortality than females at all ages except between 5 and 25 years. While the mortality is decreasing rapidly in both sexes, the decline among females is greater than that among males.

In London also there has been a steady decline. In 1910 the phthisis death-rate was 1·14 per 1,000, or 0·24 below the average rate in the five preceding years. It was as low as 0·55 in Hampstead, and as high as 1·74 in Southwark and 1·98 in Holborn.

Deaths from phthisis are most frequent in spring (March and April), and least so in autumn (September and October). The seasonal curve of mortality is therefore later than in the ordinary respiratory diseases, but it serves to indicate seasonal conditions accelerating death rather than those primarily inducing a disease of long and uncertain course.

Bacteriology.—The pathogenic microbe of tuberculosis, discovered by Koch in 1882, is a motionless, slender, beaded bacillus, straight or slightly curved along its length. The bacilli are very slow in growth and multiplication, taking one, two, or even three weeks to form a colony on artificial media, and they require for that purpose a somewhat high temperature, which must further be maintained within narrow limits, about 37° to 39° C. A peculiarity which they share with the bacillus of leprosy and the spirochæte of syphilis is that after staining with fuchsin they are not decolorized by nitric acid (Ziehl-Neelsen method). They are therefore termed *acid-fast.* (There are in addition to the tubercle bacillus a group of acid-fast bacilli allied to the streptothrix family. They possess, however, characters which differentiate them from the tubercle bacillus.) The tubercle bacillus is found in all tuberculous lesions, both in man and the lower animals, also in the blood, and in certain secretions (milk). It abounds in phthisical sputa. Cultivations if inoculated or injected into susceptible animals reproduce the disease, and this is the best method of differentiation. The bacilli are readily destroyed by many chemical or thermic means, and by prolonged exposure to sunlight. No spores are formed.

The Royal Commission on Tuberculosis (1911) distinguished three types of tubercle bacilli—human, bovine, and avian—differentiated by cultural characters and effect on animals. Man can be infected by the bovine or the human bacillus, or both.

Tuberculin. — Koch, by growing the tubercle bacillus in alkaline veal-peptone broth with glycerin for six to eight weeks, obtained a toxic fluid. After filtration and concentration by evaporation to one-tenth its bulk, *tuberculin* [T.] was obtained (containing alkaloids, albumoses, and extractives). Subsequently Koch took highly virulent cultures of the bacillus, dried them in vacuo, and triturated them. The resulting powder was treated with sterile water and centrifugalized. The supernatant fluid was removed and 20 per cent. of glycerin added (=Tuberculin O [T.O.];

or Oberer tuberculin). The solid residue was similarly treated separately (=Residual tuberculin [T.R.]). A third modification was obtained by extracting dried tubercle-bacilli with decinormal soda solution (= Tuberculin alkalinum [T.A.]). Other forms have also been produced (tuberculocidin, antiphthisin, tuberculase, bovine tuberculin, etc.). Tuberculin has been used for diagnostic and therapeutic purposes. For the former, the cutaneous reaction (von Pirquet), the percutaneous reaction (Moro), and the ophthalmic reaction (Calmette) are the common methods, in which T. is used; as a therapeutic agent tuberculin has been used subcutaneously in local and incipient tuberculosis with some success. Various antituberculous sera (Marmorek's, Maragliano's, etc.) have been invented and used, but hitherto with small success.

Mode of infection.—Tuberculosis can be acquired by inoculation, inhalation, or swallowing. Inoculation is comparatively rare, and usually causes a local lesion only. Inhalation would seem to be by far the most common source of infection. The bacilli, or rather their spores, are found in air-borne dust, especially in rooms inhabited by phthisical persons. The daily sputa of a single patient may contain many millions of bacilli, and drying for months will not destroy their virulence. The prevalence of the pulmonary form of tuberculosis, and its close relation to air-conditions, are not without significance, as pointing to air-borne infection. A further analogy to the ordinary infectious diseases is to be found in the strong evidence which has been adduced by Ransome and others to show that tuberculosis attaches itself to particular small localities ("tuberculous infective areas"), houses, and even rooms. The bacilli have been found not only in the air and dust, but in the walls of rooms occupied by phthisical persons. Cornet demonstrated this, and Coates investigated it in houses in Manchester in 1900. He found that of dirty houses in which consumptive patients were living who took no precautions to dispose of their expectoration, but spat freely upon the floor and into the pocket-handkerchief, 66·6 per cent. contained virulent tubercle bacilli. Of clean houses in which the patients were not sufficiently careful as to the disposal of the sputa, 50 per cent. contained tubercle bacilli.

Whenever tuberculous sputum is allowed to dry the risks are therefore great that the dust so produced may be inhaled in a virulent form, and, lodging at one or more points, may set up varying degrees of tuberculosis. This broad fact is based upon experimental and clinical evidence. Tuberculosis has been produced experimentally in animals in this way, and there is clinically the overwhelming frequency of tuberculosis of the lungs among men exposed to this form of infection. But Koch, Flügge, and others have shown that not only is sputum a source of infection when dried and pulverized, but also when disseminated by coughing, shouting, etc., in the form of minute moist particles of spray.* Koch exposed rabbits, guineapigs, rats, and mice to an infected spray for half an hour on three successive days, and produced tuberculosis in every animal. Heymann found that such spray particles from human beings inoculated into guineapigs produced tuberculosis. Most of the droplets are large and settle rapidly, but some may remain suspended in the air for more than an hour, retaining, of course, their virulent properties. Heymann found the duration of life of the bacilli in these droplets was eighteen days in the dark, and three days when exposed to light. In ordinary circumstances and with an absence of draughts, the zone of danger from a coughing consumptive extends to a distance of about 3 ft. It must be remembered that the tubercle bacilli in the moist particles of "cough-spray" are probably of higher virulence than those in dried sputum dust, and therefore it seems reasonable to suppose that the cough-spray is one of the most ready modes of infection. The degree of infectivity of phthisis is not, however, a very high one. It is a true infective disease, but only a sub-infectious one.

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* Mervyn Gordon in this country has confirmed these results by applying a streptococcus test for saliva (in which secretion 10 million streptococci per c.c. may commonly occur). He finds that during loud speaking bacteria may be projected by means of salivary spray a distance of 40 ft

There is still much doubt as to the frequency of direct infection from person to person, but none as to its occasional occurrence, nor as to the fact that almost all persons must frequently inhale and swallow living tubercle bacilli. Fortunately the microbe is very slow in its development, and exacting in its requirements as to temperature and surroundings, so that the vast majority that gain entrance to the respiratory tract are expelled or perish. The long duration of the disease, the wide and general diffusion of the virus, the paramount importance of predisposing conditions, and the difficulty of infection in their absence, all combine to render obscure the time and source of infection. Statistics are inconclusive even in regard to transmission of phthisis between husband and wife.

We have previously referred to the conveyance of tuberculosis by milk and meat (*see* pp. 113, 136). The risk of contracting the disease by consuming tuberculous milk and meat is undoubted, but the disease does not appear to be widely spread by these means. As regards milk, all danger of infection may be obviated by boiling, and largely prevented by using milk from tubercle-free herds (tested by tuberculin). The cooking to which meat is subjected is frequently insufficient to destroy bacilli that may be present in the deeper parts.

The heavy mortality among children from tabes mesenterica (*tuberculous peritonitis*) and *tuberculous meningitis* is urged as a confirmation of the extreme prevalence of tubercular disease, but it is probable that both of these terms are employed in the loosest way in making out certificates, and it would not be safe to place much reliance upon the tubercular nature of the majority of the cases so certified. The former disease (*tuberculous peritonitis*) has been attributed to the consumption by children of tuberculous milk. Still, however, has shown that the commonest channel of infection in tuberculosis of children is through the lung, and that infection through the intestine, as would occur if it were milk-borne, is less common in infancy than in later childhood. There is, however, substantial evidence that tuberculous milk can and does set up some form of tuberculosis (bovine or human) in the bodies of persons consuming it.

Tuberculosis often ends in recovery. The records of long series of autopsies of persons who have died of other diseases show that traces of cured phthisis are found in a proportion variously estimated as 25 per cent. and upwards. It is not in any degree protective against a further attack.

Bovine and human tuberculosis. — Since the discovery by Koch, in 1882, of the tubercle bacillus, it has generally been held that tuberculosis in man and animal is one and the same disease. Villemin (1865) was the first to maintain this identity on the results of inoculation of bovine and human tubercular matter into small animals. Chauveau (1868) carried out similar experiments upon cattle. Both workers were successful in transmitting the disease, which produced similar effects in the inoculated animals. Many other workers have obtained like results, which were more or less uniformly in support of the identity of bovine and human tuberculosis. The Royal Commission on Tuberculosis, 1895, said: "We regard the disease as being the same disease in man and the food animals, no matter though there are differences in the one and the other in their manifestations of the disease; and we consider the bacilli of tubercle to form an integral part of the disease in each, and (whatever be its origin) to be transmissible from man to animals and from animals to animals. Of such transmission there exists a quantity of evidence, altogether conclusive, derived from experiment."

It was, however, conceded on all hands that tuberculosis was a more virulent disease in animals than in man, and that the bacillus in the two species differed in morphological, cultural, and pathological properties. In 1901, at the London Congress on Tuberculosis, Koch expressed the opinion that, "human tuberculosis differs from bovine, and cannot be transmitted to cattle," and that bovine tuberculosis was scarcely, if at all, transmissible to man. On the same occasion counter-evidence was produced by MacFadyean, Ravenel, Crookshank, and many others.

Koch based his opinion upon the negative results which followed the feeding of six cows with human tubercular sputum, making four others inhale human tubercle bacilli, and otherwise infecting nine more. None of the nineteen cattle suffered, and no tuberculosis was found in their body tissues post mortem. When, however, such cattle were infected with bovine disease they contracted it. Swine were also fed in a similar way, with like results.

In 1902 Koch again emphasized the comparative rarity of primary intestinal tuberculosis in the human being, and the local, as distinguished from the general, infective nature of accidental bovine inoculation of man (*tuberculosis verrucosa cutis*). In isolated cases the nearest lymph-glands might become affected, but the disease remained nevertheless a local one. Koch further expressed the view that if bovine tuberculosis was transmissible to man by means of the milk of cows with tuberculous udders, it would be reasonable to suppose that "groups of illnesses" would occur, in a manner analogous to other infective diseases, though the circumstances would differ owing to the different length of the incubation periods. To carry conviction as to milk-borne tuberculosis, Koch maintained that the following conditions must be fulfilled: (i.) Certain proof of tubercle in the person affected; (ii.) exclusion of other sources of infection; (iii.) the condition of all the consumers of the suspected milk; (iv.) the exact source of the suspected milk, particularly in respect to the disease of the udder of the cow yielding the milk. Finally, he concluded that all that can be said was that the injurious effects of milk infected with bovine tuberculosis and its products are not proven.

As a result of the wide differences of opinion revealed by the pronouncement of Koch's views, special Commissions of Inquiry were instituted in Germany, Great Britain, and other countries, in addition to the individual research work carried out by many workers.

Kossel, Weber, and Heuss, who carried out a comparative research upon tubercle bacilli of different origins for the German Imperial Health Office, made a number of experiments on calves by injecting some forty different strains of human bacilli and fifteen strains from cows, fowls, and swine. They concluded (1904) that in a preponderating number of cases of human tuberculosis bacilli occur which were found distinguishable from the bovine bacilli of *Perlsucht* morphologically, culturally, and in pathogenic properties, but that exceptionally in man tubercle bacilli occur which cannot be distinguished. They held that the possibility of infection in man in certain circumstances by milk from tuberculous udders is proved. They found that generalized tuberculosis was produced in animals by injecting strains of tubercle bacilli obtained from tuberculous diseases in children.

A Royal Commission was also appointed in this country, and in an interim report (1907) concluded that bovine and human tuberculosis was generically one and the same disease, though wide variation in degree of virulence may occur; that the human body can be infected by the bovine tubercle bacillus and the bovine body by the human tubercle bacillus; that in a certain number of cases human tuberculosis, especially in children, is the direct result of the introduction of the bovine bacillus, in the majority of cases through cow's milk; that "cow's milk containing bovine tubercle bacilli is clearly a cause of tuberculosis, and of fatal tuberculosis, in man"; that a very large proportion of tuberculosis contracted by ingestion is due to tubercle bacilli of bovine source; that a very considerable amount of disease and loss of life, especially among the young, must be attributed to the consumption of cow's milk containing tubercle bacilli; and that on this account the findings of the Commission point clearly to the necessity of measures more stringent than those at present enforced being taken to prevent the sale or consumption of such milk.*

The Third Report (1909) dealt with certain conditions of the tuberculous cow which rendered her milk infectious. The Final Report (1911) concluded that there were three types of tubercle bacilli, bovine, human, and avian; that the first two forms produce disease in man; that the two types are varieties of the same bacillus, and the lesions which they produce in man or animal are manifestations of the same disease; that there is insufficient evidence to determine whether avian tuberculosis is the same disease as bovine or human tuberculosis; that mammals and man can be reciprocally infected with the disease; that a considerable proportion of tuberculosis in children is of bovine origin, more particularly that which affects primarily the abdominal organs and cervical glands, and is derived from cow's milk. The Commission "urge action in order to avert or minimize the present danger arising from the consumption of infected milk."

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* Second Report, Royal Commission on Tuberculosis, 1907, pp. 20–37.

Means of prevention.—Chief among the means of prevention are good personal health, nutrition, and resistance, improvement in the sanitary environment, and educational measures, comprising instruction of the general community, those directly exposed to infection, and those already tuberculous. Nor must the teaching of school hygiene be neglected. Knowledge of the conditions under which tuberculosis is transmitted, of the channels of infection, of the appropriate destruction of sputum, etc., is most desirable. This knowledge should be conveyed in a personal and practical way. Secondly, early diagnosis, by means of bacteriological and clinical examination, is of great importance as a preventive measure. Medical inspection and care of children also has its place in the early detection of the disease, and particularly in such treatment as the removal of adenoids and the reduction of measles. Thirdly, notification of tuberculosis to the local **M.O.H.** is a direct means of introducing preventive and curative methods (Public Health [Tuberculosis] Regulations, 1912). Fourthly, industrial betterment, removal of dust, and factory sanitation protect the worker. Lastly, there is need for a national scheme of organized investigation and treatment. This was recommended by the Astor Departmental Committee on Tuberculosis, 1912.

The first unit of the scheme is the *tuberculosis dispensary*, providing for the careful investigation of each case, followed by advice, cleansing, disinfection, the avoidance or removal of certain channels of infection, the provision of spit-bottles, etc. Home training and constant supervision are often called for. The tuberculosis dispensary provides a means for investigation and treatment by domiciliary visitation, by nurses, health visitors, and others. It has six functions, viz.: (1) receiving-house and centre of diagnosis, (2) clearing-house and centre for observation, (3) curative centre, (4) clinic for examination of contacts, (5) after-care, (6) information bureau and education.

The second unit is the *sanatorium.* Under the Public Health Act and the Insurance Act the Sanitary Authority and the Insurance Committee have power to provide such treatment for suitable patients. Huts, tents, isolation hospitals, and private houses may all be adapted to this object, and under appropriate management yield good results equally with the elaborately equipped sanatoria in ideal situations. Sanatorium treatment may arrest or cure early phthisis, and affords isolation and education for all cases (with appropriate after-supervision). Isolation and treatment are not only of value to the patient, but aid indirectly in protecting the community. Structure and equipment will depend on the type of case to be admitted (*see* p. 278). Children should be treated in special sanatoria, and separate arrangements should be made for non-pulmonary and advanced cases. The sanatorium for early cases should provide for the open-air life, ample food, and graded exercises and occupation, increasing as the patient becomes convalescent. The length of residence will necessarily vary, but for the patient's sake should not be less than about six months. If cases are properly selected they should be retained until sufficiently recovered to return to work and ordinary life or to an intermediate institution. The desirable sequence is tuberculosis dispensary (for early diagnosis and home treatment) followed by sanatoria having farms and colonies, and effective after-care arrangements.*

VENEREAL DISEASE

The three chief forms are syphilis, gonorrhœa, and soft chancre. From the end of the fifteenth century **syphilis** has been endemic in Europe. In 1905 Schaudinn and Hoffmann discovered the causative protozoon, the *Spirochæta pallida* (Fig. 63), which may be found in the blood, discharges, or diseased organs. Syphilis may be acquired by direct or indirect contagion, or it may be hereditary. Ricord recognized three stages—primary, secondary, and tertiary. The average incubation period is about

Fig. 63.—Spirochæta pallida. × 2,000. (*McDonagh.*)

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* *See also* Special Report of Local Government Board on Sanatoria for Consumption (*Bulstrode*), 1905–6 (published 1908 ; *and* Report of Departmental Committee on Tuberculosis, 1912 (and Appendix).

25–30 days. The primary infection may be genital or extragenital. The spirochæte enters through some crack or fissure of the skin or mucous membrane, with the result that a papule or pimple is formed which becomes the syphilitic sore or "chancre," oval or round, red, indurated. In a few days the nearest lymphatic glands enlarge. The commonest sites of the chancre are the genital organs, fingers, and face (lips, tongue, mouth). About the seventh week after the chancre, evidence of the dissemination of the spirochæte occurs in irregular pyrexia, skin eruptions, lymphatic generalization, and disease of organs. These secondary skin eruptions are polymorphic, widely distributed, and non-irritative, and include macular, papular, squamous, and follicular syphilides, resulting sometimes in rupia, condylomata, keratodermia, etc. Subsequently, in the tertiary stage, appear "gummata" in various organs, bone disease, and affections of the arteries and the nervous system, leading to grave complications—locomotor ataxia, optic atrophy, and general paralysis (parasyphilis or quaternary syphilis).

Hereditary syphilis (inherited by germinal infection or through the placental circulation) attacks tissues in process of development, and when present manifests itself in a high proportion of stillbirths or miscarriages, or in symptoms corresponding to secondary syphilis ("snuffles," skin eruptions, "syphilitic wig," condylomata, iritis, choroiditis, interstitial keratitis, craniotabes, Hutchinsonian teeth, various nervous conditions, etc.).

Syphilis is infective in all stages, but particularly in its primary and secondary periods. It is spread by direct contact, and in 90 per cent. of cases in sexual intercourse. It is occasionally conveyed by kissing, suckling, etc., and indirectly by utensils, tobacco-pipes, etc. Many persons are innocently infected, perhaps 25 per cent. of all women infected. Much syphilis is spread by infected males, ignorantly or recklessly, and one syphilitic prostitute may infect scores or even hundreds of men. Erb estimated that 12 per cent. of the population of Berlin is syphilitic, and probably the proportion in Paris, London, and other large towns is similar. The mortality statistics are inadequate and unreliable. In 1914 the mortality in England and Wales was 58 per million (approximately 70 per cent. being children under 5 years). There has been for some years a decline, apparent or real, in syphilis in the Army and Navy, but special inquiries in hospitals, prisons, and asylums have shown by the Wassermann test an incidence varying from 5 to 15 per cent. Mortality returns for syphilis do not include general paralysis of the insane, nor stillbirths and premature births, nor many infant deaths. Of 1,001 pregnancies of syphilitic women, only 390 yielded healthy living children (*Harman*); in another 175 of such pregnancies there were only 30 healthy children (*Mott*).

Gonorrhœa is a specific urethritis due to infection by the gonococcus, discovered by Neisser in 1879. The gonococcus is a diplococcus, kidney-shaped, situated within the pus cell (Fig. 64). It is decolorized by Gram stain and difficult of culture. The disease is liable to chronicity and is hard to cure unless treated in its earliest stages. Its complications are epididymitis (causing sterility), cystitis, and urethral stricture; in the female, endometritis and salpingitis may occur, often with sterility. Gonorrhœal septicæmia and ophthalmia are dangerous complications. The latter occurs also in new-born children. The disease is spread by contact, and is more common than syphilis.

Soft chancre is a venereal sore, to be distinguished from the indurated syphilitic lesion. It is painful, multiple, accompanied by enlarged but not hard glands, has a short incubation period, and gives rise to no generalized disease.

In 1913 the **Royal Commission on Venereal Diseases** was appointed. It reported (1916) that the effects of venereal disease upon the individual and the race are grave and far-reaching, and that by early and effective treatment it could be greatly reduced. This treatment, so far as syphilis is concerned, is now available by the discovery of the cause of syphilis in 1905, the elaboration of the Wassermann test in 1906, and the synthetization of salvarsan, or "606," by Ehrlich in the same year. The Commission recommended various methods of treatment, which were subsequently provided for in

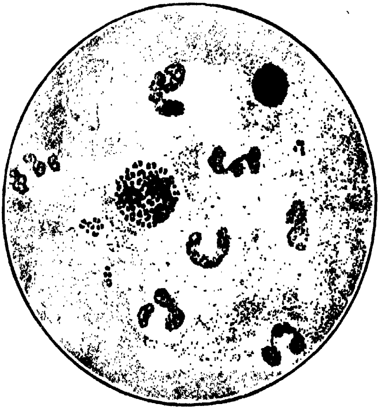

Fig. 64.—Gonococci and pus cells with irregular nuclei.
(*Leedham-Green.*)

the **Public Health (Venereal) Regulations, 1916.** Every county and borough council is required (*a*) to make arrangements for enabling medical practitioners to obtain, free, examination of material from venereal patients, (*b*) to prepare a scheme for treatment at or in hospitals, and for the supply of salvarsan or its substitutes. Authorities may also make arrangements with hospitals for the purposes of the Regulations, and provide for instructional lectures or the publication of information. The **L.G.B.** repay 75 per cent. of approved expenditure incurred. The methods adopted by the Authorities are the establishment of clinics and in-patient accommodation and the provision of ample laboratory facilities for diagnosis and treatment (including examination of discharges, fœtal tissues, and other materials, Wassermann tests, and the supply of salvarsan, its substitutes, and mercurial preparations).

The **Venereal Diseases Act, 1917,** empowers the **L.G.B.** to forbid the treatment of venereal disease in any area otherwise than by duly qualified medical practitioners. Restriction is also placed upon medical advertisements and quack medicines.

Salvarsan belongs to the group of aromatic arsenic combinations (dioxydiamido-arsenobenzol), and is administered in solution by intravenous injection. Three to seven injections are given at intervals of eight days or longer; it is usually combined with mercury. The spirochætes are destroyed and the disease usually disappears rapidly.

Wassermann's test depends upon the reaction which takes place between (*a*) an antigen and (*b*) its specific amboceptor (antibody) in the presence of (*c*) complement (*see* p. 379), in the course of which the complement becomes fixed and disappears. If the antibody is not the specific antibody for the antigen used, no reaction takes place, and the complement remains free. The fixation or non-fixation of the complement is ascertained by means of the Bordet-Gengou phenomenon the addition of another antigen and its antibody whose reaction in the presence of complement is known to have visible results. If the complement has been fixed, no reaction ensues;

but if it has not been fixed, the visible reaction takes place and demonstrates the fact. The blood serum of the syphilitic patient contains the antibody; the antigen used is usually prepared from syphilitic liver (or a mixture of heart-extract and cholesterol), and the complement is added. The test is carried out as follows: Cleanse the skin at the bend of the elbow with alcohol; collect with a sterile hollow needle 5–10 c.c. of blood from a vein; place the sample of blood in a sterilized centrifuge tube, and plug the tube; separate the clot from the serum, and inactivate the serum by heating at 56° C. for one hour. To a series of test-tubes add (*a*) varying quantities of the serum, (*b*) a standardized quantity of antigen (syphilitic liver, or a mixture of heart-extract and cholesterol), and (*c*) a standardized quantity of complement (fresh guineapig serum). Make up each tube to constant volume with normal saline solution. Incubate at 37° C. for one hour, and add a mixture of washed sheep's corpuscles and a standardized quantity of hæmolysin. Incubate again for one hour; remove to an ice-chest for several hours before examination. If syphilitic antibodies are present no hæmolysis will occur and a "positive" reaction is obtained, the corpuscles being at the bottom of the tube and the clear fluid above.

RABIES (HYDROPHOBIA)

There are two chief forms, "furious" and "paralytic." The former is the commoner in dogs. The disease is comparatively rare in man, but is one of interest and importance from the point of view of preventive medicine. There were 761 deaths from hydrophobia in England and Wales between 1866 and 1885, and none during the six years 1899–1904, except 2 in 1902.

Hydrophobia causes most deaths at ages between 5 and 15 years; more among males than females; and more in late summer and autumn than at other seasons (*Longstaff*).

The disease is imparted to man by the bites of rabid dogs; or, more rarely, of rabid cats, foxes, or wolves. The ordinary incubation period is six weeks. It is stated to have been as short as one week in children bitten about the face. The disease almost invariably ends in death within a few days. It is not known to have been transmitted from one human being to another. Bites about the face are more deadly than others, and in such cases the incubation is short. The danger is less when the part bitten is protected by clothing. Taking only cases of bites by animals proved beyond doubt to be rabid (the proof being the occurrence of a genuine case of rabies in some person or animal bitten by them or inoculated from them), hydrophobia manifests itself in about 15 per cent. of the persons bitten.

Pasteur discovered that the virus, though absent from the blood, is present in the spinal cord of rabid animals as well as in the saliva, and that a portion of the spinal cord of a rabid animal (or human being dead from hydrophobia), inoculated beneath the dura mater of a rabbit, imparts the disease with certainty. Further, he demonstrated that the infected cord gradually loses its virulence if kept in perfectly dry air, and that this attenuation affords a means of curative or protective inoculation. He inoculated at short intervals with successively more and more virulent material, commencing with very attenuated virus (after fourteen days' drying), until at last three-days-old cord was employed. It is surmised that the protection is due to a chemical substance, and not to any real attenuation of the microbe. However this may be, the result of the course of inoculations—so far from causing rabies, as a single inoculation with fresh rabic cord would do—is to render dogs insusceptible to rabies. The same treatment is now extensively practised in regard to persons bitten by rabid animals; and the mortality among such, under early treatment, is no longer 10, but a fraction of 1 per cent. In the decennium 1893–1902, on an average, 1,450 persons were treated annually at the Pasteur Institute in Paris, and the rate of mortality was 0·32 per 1,000. In 1903-12 the rate fell to 0·23 per 1,000.

The microbe has not been isolated with any certainty, although both micrococci and bacilli have been found in the rabic cord.

Rabies can be stamped out by muzzling all dogs for a sufficient length of time. This was done in Sweden many years ago, and the country remains free from rabies. Less isolated countries are subject to constant new importations of the disease across the frontiers, but the success of repressive measures has been very great. Thus hydrophobia, though formerly prevalent, has been unknown in Berlin since 1874, and the Prussian provinces are practically free except on the eastern (Russian) frontier.

In England several local attempts were made in the same direction, but none upon a large scale until 1890, when it was made compulsory for a time throughout Lancashire, Cheshire, the West Riding, and London, and was followed by the cessation of rabies. In London muzzling was adopted in 1885, and again, as well as in many other areas, in 1919. The Rabies Order of 1892, issued by the Board of Agriculture, enables county Authorities to make regulations for muzzling and other preventive measures, and the Importation of Dogs Order of 1901 has served as a great protection to the United Kingdom.

GLANDERS, OR FARCY

This disease, as affecting man, was only described during the last century. Although in isolated instances it has been transmitted from one human being to another, it is practically always acquired from the horse. *B. mallei* does not appear to be capable of aerial transmission, except, perhaps, for very short ranges, and nothing is established as regards convection by water or milk. The bacillus is slender, Gram-negative, and occurs in discharges. It stains with carbol-thionin blue. Inoculation is the almost invariable mode of infection so far as man is concerned; but it is probable that this may sometimes occur without abrasion of skin or mucous membrane. Among animals the disease spreads rapidly. It is very rare in man, but attended with an extremely high mortality, which is stated to be not less than 50 per cent. in chronic cases, and not far from 100 per cent. in the acute variety. The usual incubation ranges from three to eight days, and is shortest in acute cases. For obvious reasons, men are much more liable to glanders than women or children. The disease affects the nasal and respiratory mucous membranes, and also the lymphatic glands. When the latter are attacked first, the disease is termed *farcy*.

ANTHRAX

Man is affected by anthrax in two forms, external and internal. External anthrax, or "malignant pustule," has its usual seat about the face or neck, and is, no doubt, due to inoculation. The first local manifestation is the appearance of a papule or vesicle, which develops in the course of a few days into an inflamed indurated mass with a central black slough. The border may be fringed with vesicles or inflamed. The surrounding tissues and the lymphatic glands are swollen and indurated. The disease may remain localized, and end in resolution, or at most in suppuration. Usually, however, constitutional symptoms attend its course, and general infection may follow. Occasionally, malignant pustule supervenes upon internal anthrax. Internal anthrax appears to be due to inhalation or swallowing of the poison. After a very variable incubation period, ranging perhaps from two to twelve days, the early symptoms are chills, weariness, depression, restlessness, and a feeling of constriction in the chest. This prodromal stage may last only a few hours, but more usually two to six days, and then graver symptoms set in suddenly. The prostration becomes extreme; pulse and respiration are rapid. The temperature is somewhat elevated, but always liable to sudden remissions, accompanied by perspiration. The patient may die from heart-failure, or brain symptoms may become prominent, or pneumonia or diarrhœa may supervene. Remissions may occur. The mortality is high, but recovery may happen even in serious cases. The protection derived from an attack is very slight, if any.

Anthrax received the name of "wool-sorters' disease" from its prevalence among men employed in sorting foreign wool and hair. Tanners, butchers, and persons engaged in handling raw hides or horse-hair are liable to malignant pustule.

Anthrax attacks sheep, goats, pigs, cattle, and horses, and may be communicated to mice, guinea-pigs, and many other animals. As in man, the disease may be either localized or constitutional, and in the latter variety enlargement of the spleen is so prominent a characteristic that anthrax is known as "splenic fever." A field may become infected with anthrax, and healthy animals turned into it after the lapse of months, or even years, may acquire the disease. The infection is probably imparted to the superficial layers of soil by the blood or secretions of affected animals, in which the resistant spores form. Other sources of infection of animals are the use of infected dust or other trade refuse as manure, and drinking from streams receiving infected trade effluents.

Although exact evidence is wanting, it may be assumed that anthrax can be acquired by eating the flesh of diseased animals. The usual modes of infection in man are by inoculation and inhalation, and it has been suggested that the poison may be carried by flies and other insects.

Bacteriology.—The pathogenic organism is the *Bacillus anthracis* (Fig. 65), which forms spores when exposed to air. The bacillus, which grows readily on ordinary media, is square-ended, 1 μ broad and 4–5 μ long, sometimes in filaments; aerobic, non-motile, liquefying; chiefly occurring in the spleen and blood-stream, and readily destroyed by heat or other disinfecting agencies, though the spores are extremely resistant. It has been found that animals can be infected by inhaling or swallowing the spores, but not by the bacilli unless there is some abrasion such as to allow practically of inoculation. Bacilli are destroyed by the gastric juice, spores are not.

Martin has shown that the *Bacillus anthracis* produces albumoses, which in turn yield toxins much more virulent than themselves. Sclavo of Siena has prepared an *anti-anthrax serum* from which excellent results have been obtained, reducing the case-mortality from 24 to 6 per cent. The animal used for immunization is the ass, which is inoculated with slowly increasing doses of virulent cultures of the anthrax bacillus. Blood is drawn from the left jugular vein, and after clotting the serum is decanted and ether added to the extent of 3 per cent. of the whole bulk.

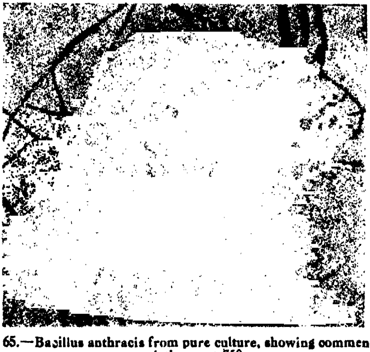

Fig. 65.—Bacillus anthracis from pure culture, showing commencing sporulation. × 750.

The serum is then bottled with antiseptic precautions in 10 c.c. tubes.

In external anthrax early excision is of the greatest importance, and usually results in recovery.

Cases of anthrax in horses, cattle, sheep, pigs, etc., are dealt with under the Anthrax Order of 1910, issued by the Board of Agriculture. The owner reports the outbreak to the inspector specially appointed for the purpose by the local Authority. It is the inspector's duty to inform the **M.O.H.** and to direct precautionary measures as to isolation, disinfection, and destruction of the carcass, as prescribed in the Order.

TETANUS

This disease occurs in man and horses most commonly, though it may affect other animals. There is usually a wound, often an insignificant one, which may occur in any part of the body, but is nearly always on one or other of the limbs. It is not the locality of the wound, nor its size, that affects the disease. Wounds which are jagged, and occurring in absorptive tissues, are those most fitted to allow the entrance of the bacillus. The wound forms a local manufactory, so to speak, of the bacillus and its secreted poisons ; the bacillus remains in the wound, but the toxins may pass throughout the body, and are especially absorbed by the cells of the central nervous system. Suppuration generally occurs in the wound. After a few days or, it may be, as much as a fortnight, when the primary wound may be almost forgotten, general symptoms occur. Their appearance is often the first sign of the disease. Stiffness of the neck and facial muscles, including the muscles of the jaw, is the most prominent sign. This is rapidly followed by spasms and local convulsions, which, when affecting the respiratory or alimentary tract, may cause a fatal result. Fever and increased rate of pulse and respiration are further signs of the disease becoming general. After death, which results in the majority of cases, there is very little to show the cause of fatality. The wound is observable, and patches of congestion may be found on different parts of the nervous system, particularly the medulla (grey matter), the pons, and even the cerebellum. The experience of the Pasteur Institute tends to support the theory that tetanus is a "nervous" disease, more or less allied to rabies, and is best treated by intracerebral injection of antitoxin, which then has an opportunity of opposing the toxins at their favourite site. The toxins diffuse throughout the tissues of the body, but particularly affect the spinal cord. The long incubation period indicates that the toxins are probably produced by a ferment which is an extremely powerful poison.

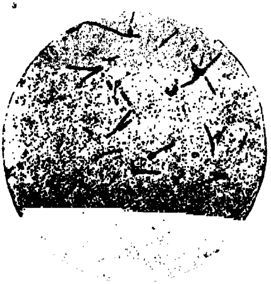

Fig. 66.—Bacillus tetani from pure culture. × 1,000.

Bacteriology.—In the wound the bacillus (Fig. 66) is present in large numbers, but mixed up with a great variety of suppurative bacteria and extraneous organisms. It is a straight short rod with rounded ends, occurring singly or in pairs or threads, and slightly motile. Flagella may be demonstrated (lateral and terminal). Branching also has been described. Indeed, it would appear that, like the bacillus of tubercle, this organism has various polymorphic forms. A large round spore occurs at one or other pole of the bacillus ("drumstick" appearance). The spores are very resistant. The bacillus is an anaerobe, stains with the Gram, and grows at blood-heat. In some soils it is common, and infection has frequently been derived from dust in jute factories, etc. *Antitoxic serum* is used. The usual method is intraspinal injection by lumbar puncture, followed by intravenous injection (5,000 U.S.A. units in each case). Intracerebral injection is also employed. The prophylactic dose is 500–1,000 units.

PUERPERAL FEVER

In 1915 the number of deaths assigned to pregnancy or childbirth was 3,408, or 4·18 per 1,000 births, principally from puerperal fever, hæmorrhage, and convulsions. The means of prevention are—(1) improved health of the mother, (2) aseptic midwifery, (3) skilled medical service and midwives, (4) antenatal consultations and clinics.

ANNUAL DEATH-RATES FROM EPIDEMIC DISEASES

The incidence and fatality of the infective diseases form one of the essential measurements of the public health. The incidence is recorded by notification or reports of cases, the fatality by the respective death-rates. The attached Table (p. 494) gives the annual death-rates per million living from the principal epidemic diseases in England and Wales (1871–1915). The death-rates for measles and whooping-cough under 15 years of age, the total infant mortality under 1 year of age, and the crude death-rates from all causes have been added for comparative purposes, It will be noted that, with the exception of diphtheria, all the death-rates have declined, smallpox and typhus to the vanishing-point. The death-rate of smallpox was 576 per million in 1838–42, so that its decline is the most remarkable, but the fall in the death-rates of typhus, enteric, and scarlet fever is significant.

ANNUAL DEATH-RATES FROM EPIDEMIC DISEASES PER MILLION LIVING, ENGLAND AND WALES

Period.	Small-pox.	Measles.	Scarlet fever.	Diphtheria.	Diphtheria and croup.	Whooping-cough.	Typhus.	Enteric.	Measles (under 15 only).	Whooping-cough (under 15 only).	Total infant mortality rate —per 1,000 births.	Crude death-rate at all ages per 1,000 living.
*1871–75..	411	373	759	121	305	499	81	374	1,023	1,378	153	22·0
1876–80..	78	385	680	122	276	527	34	277	1,051	1,450	145	20·8
1881–85..	78	413	436	156	320	459	23	216	1,138	1,269	139	19·4
1886–90..	14	468	241	170	295	444	7	179	1,313	1,250	145	18·9
1891–95..	20	407	182	253	323	398	4	174	1,174	1,151	151	18·7
1896–1900	7	421	135	272	307	359	1	175	1,260	1,079	156	17·7
1901–05..	25	327	126	205	222	301	1	113	1,016	940	138	16·0
1906–10..	0	291	86	154	162	253	0	70	930	813	117	14·7
1911.. ..	1	363	52	135	137	217	0	67	1,176	707	130	14·6
1912.. ..	0	352	55	118	119	230	0	44	1,144	751	95	13·3
1913.. ..	0	291	57	121	122	149	0	41	940	486	108	13·8
1914.. ..	0	247	77	158	159	218	0	46	801	709	105	14·0
1915* ..	0	462	66	165	166	230	0	35	1,414	708	110	15·7

* Civil population only.

CHAPTER XIV

TROPICAL DISEASES

In this chapter will be considered briefly some of the chief tropical diseases. Many diseases, such as pneumonia, diarrhœa, typhus, and typhoid, occur, of course, in sub-tropical and tropical countries; but such diseases as cholera, yellow fever, plague, malaria, relapsing fever, and leprosy have their origin or at least their home in the tropics.

ASIATIC CHOLERA

Cholera has its endemic area in certain parts of India, including the delta of the Ganges. The first great epidemic in India occurred in 1817. At irregular intervals it spreads in epidemic or pandemic form over a great part of the world. It follows the lines of traffic by land or water, but no reason has been found for the apparently capricious selection of some routes and omission of others. The invasion of each new country along its line of march is almost invariably traceable to infection through some point of communication with a country already attacked. In temperate climates the outbreak often subsides or disappears in winter, but frequently reappears with the warm weather in the late spring or early summer; and may even recur again in the third year, apparently without fresh introduction. In India, from 1896 to 1913, seven million deaths were caused by cholera.

Cholera gained a firm footing in England on four occasions. viz. 1831-2, 1848-9, 1853-4, and 1865-6, the epidemic extension from India having occupied respectively five, two, one, and two years in transit.

In 1831 infection was carried to Sunderland and Newcastle, from Baltic ports, in October, and in the course of the next year caused great mortality throughout the kingdom. The system of registration of deaths was not then in operation, but, according to Hirsch, the total mortality in England was 30,924. In 1848 Hull was infected from Hamburg early in October, and the disease at once spread. Only 988 deaths were recorded in England from October to March, but the epidemic made rapid progress in the summer, and before its final disappearance in December, 1849, it had caused 53,293 deaths, besides a heavy diarrhœa mortality, part of which may be supposed to have been due to cholera. In 1853–4 the invasion was again from Germany, London being attacked in August. The outbreak continued through the winter, especially in the north; became more active in July, 1854, and overran the country, causing during the year 20,097 deaths in England and Wales. The 1865–6 epidemic was milder, but still resulted in 14,378 deaths.

On several other occasions the disease has invaded Europe, but failed to reach England, notably in 1871–4 and 1884–7. In 1892 it again spread to many parts of Western Europe, notably Hamburg, but, apart from imported cases, none appeared in England until September, 1893, when a few occurred at Grimsby, Hull, and elsewhere. Since then only small isolated outbreaks have occurred in this country. From 1907 the disease became prevalent in Russia, and passed down the rivers into East Prussia.

Climate, season, and temperature.—Heat is a predisposing condition, but cold does not necessarily arrest the disease. Severe epidemics have occurred in Sweden and Russia in the depth of winter. Rainfall and telluric conditions also exert influence in its prevalence.

Even in India the seasonal curve of cholera prevalence is by no means always parallel with that of temperature. Generally speaking, in Bombay the maximum of cholera deaths is in April; in the N.W. Provinces and the Deccan in August; in Madras there are two maxima, in January or February and September; and in Calcutta a chief maximum in April and a smaller one in November. In all these regions, except one, the highest mean temperature is reached in May; in the N.W. it is in June. In Madras cholera mortality is at its minimum in June, when the mean temperature is at its highest. In Europe, as a rule, epidemics attain their maximum in August, but sometimes in September or July.

Epidemiology.—Cholera is carried by man (patients, convalescents, contacts), and is closely associated with his personal habits. In Europe and America it enters at seaports, in Asia it follows the fairs and pilgrimages. Epidemics are especially apt to follow the low-lying districts along banks of rivers and lakes, whether navigable or not. Hilly regions seem to escape frequently, although outbreaks may occur on high ground. The influence of elevation is often recognizable even in the distribution of cholera in a single town. Particular quarters, streets, and even houses are often selected for attack in a town invaded by cholera, and the selection can usually be explained by the existence of overcrowding and some filth condition in or about the houses, some pollution of water supply, or other insanitary condition. **Drinking-water** above all things has been closely associated with cholera in England and India.

A few classical instances may be quoted here. The 1849 epidemic was very fatal in a part of London supplied mainly by two water companies—the Southwark and the Lambeth—both of which distributed polluted Thames water after imperfect filtration. The incidence of cholera was substantially the same upon the customers of both companies, whose mains supplied the same districts and even houses in the same streets. In 1854, however, the population supplied by the Southwark Company suffered in 14 weeks a mortality from cholera of 13 per 1,000, and the customers of the Lambeth Company only 3·7 per 1,000. The disease singled out the houses supplied by the Southwark Company, whose intake remained as in 1849; while the Lambeth Company had in the meantime obtained a purer supply from a point many miles higher up the river.

The 1866 epidemic in London chiefly affected Poplar, and Netten Radcliffe found a similarly close coincidence between the area affected and the distribution of polluted water by the East London Company. In 1854 a sudden and intense outbreak occurred among the inhabitants of a small area near Golden Square, upwards of 400 persons being attacked within five days. The incidence of the disease was limited to those who had drunk the water from a pump in Golden Square—including persons residing at a distance who had sent for the water—and upon investigation the well was found to be polluted with sewage. A few fatal cases had occurred in the vicinity during the month previous to the outbreak, and there was strong probability of specific pollution of the well.

More recently, the experience of Hamburg, Altona, and other places has afforded further proof of the possibility of convection of cholera on a large scale by drinking-water.

Race.—The incidence and severity are greater among negroes than Europeans, but apparently less among natives of hot countries in which cholera occurs than among European settlers.

Insanitary conditions of air, water, food (including milk), soil, drainage, and housing determine the points of attack. Excremental filth is most dangerous of all. Infection may be carried by flies.

The poison doubtless gains access to the system by inhalation or swallowing. The incubation period is stated to be usually a few hours to three days, but may reach ten or even twenty days (*Parkes*). Clinically, cholera is marked by profuse watery stools, like thin rice-water containing white flocculi in suspension. Vomiting, cramps, suppression of urine, cyanosis, and collapse often ensue. Hyperpyrexia is a rare occurrence, but sometimes the patient passes into the typhoid state with various complications. The mortality is, as a rule, not far short of 50 per cent. of the cases, and may be greater. Infection is given off in the discharges from the bowels, and probably in the vomit also. These may infect water, soil, or fomites.

Bacteriology.—In 1883 Koch isolated from cholera discharges a microbe which from its shape received the name of "comma" bacillus (Fig. 67). It is a curved rod, often about half the length of the tubercle bacillus, and motile. Strictly speaking, the "comma" bacilli are segments of a spirillum or vibrio, and not true bacilli. They are present in choleraic evacuations, generally, if not always, in spirillum form They occur in the intestinal wall and in the detached flakes of mucous membrane, in which they often lie in parallel arrangement, creating the "fish in stream appearance" under the microscope. They do not occur in the blood, and but little in the body generally.

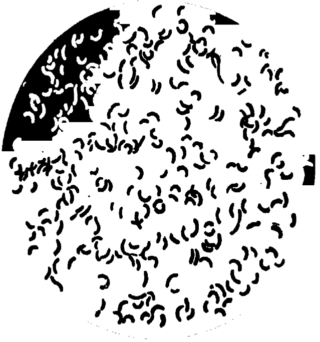

Fig. 67.—Cholera bacillus, 24 hours' growth. × 1,000.
(*Muir and Ritchie.*)

The bacillus liquefies gelatin and grows in involution forms, but does not produce spores. It is stained by ordinary aniline dyes, but not by Gram's method. In cultures it grows aerobically, and produces nitrates, but can be acclimatized to anaerobic conditions, and is then more virulent but less resistant. The organism produces characteristic growth on the ordinary media, and produces indol, which, with the nitrates, gives a red reaction on addition of sulphuric acid (nitroso-indol). This test is known as "the cholera-red reaction." The bacilli are killed by acid liquids, so that they cannot live in presence of the acid gastric juice, but it has been shown that the contents of the stomach may remain alkaline if only liquids are taken. Koch neutralized the gastric juice of fasting guineapigs by alkali, checked the peristalsis by opium, and then introduced cultivations of comma bacilli into the stomach. The animals died in a day or two, the intestines being filled with fluid containing numbers of comma bacilli.

Broadly, the reasons for believing Koch's comma bacillus to be the cause of cholera are—(*a*) its constant presence in cases of the disease ; (*b*) the results of accidental infection ; (*c*) the agglutinative and protective properties of the serums of cholera patients ; (*d*) the result of Haffkine's preventive inoculation with his two vaccines (*see* below).

Vaccination.—Koch's bacillus has been "intensified" in various ways, and is then pathogenic to lower animals, including dogs and rabbits. It has also been attenuated, and a protective "vaccine" has been obtained. Haffkine prepares two vaccines, the weaker of which is made from cultures of the bacillus attenuated, and the *virus exalté* from similar cultures, the virulence of which has been increased by passage through animals. The first vaccine is inoculated, and followed, three or four days afterwards, by the second.

YELLOW FEVER

This disease has its endemic areas in the West Indies and certain parts of the Mexican and West

African coasts. Among European countries only Spain and Portugal come practically within its epidemic range. Infected ships reach European ports, but without causing any spread of the disease.

In the endemic area the greatest prevalence is between April and September, but in higher latitudes the epidemics occur in summer and autumn, beginning usually in July and August, and never lasting beyond December. It is only endemic in regions where the mean temperature reaches about 75° F., and epidemics do not as a rule occur in any latitude unless the temperature is above that point. A fall below 75° F., however, will not necessarily arrest the course of an epidemic when once begun, though it will usually cause a remission, but frost always arrests it more or less completely. According to Hirsch, atmospheric humidity and rainfall are as a rule favourable to yellow fever, unless accompanied by great lowering of temperature. With few exceptions the incidence of the disease is limited to the sea coast and the shores of great navigable rivers; only in intense epidemics does it affect elevated points. Even in the West Indies it rarely extends as high as 700 ft. above the sea.

Predisposing conditions.—Yellow fever is a disease of towns, and has a strong tendency to localize itself in certain quarters, streets, or blocks of houses. Successive epidemics frequently single out the same local foci. As a rule these are in the filthiest and most crowded parts, where insanitary conditions of every kind abound, and more especially excremental pollution of the air, soil, and water. Outbreaks frequently occur on board ship, and, if virulent, are usually associated with similar filth conditions.

Telluric conditions have probably some influence, but the disease is not known to be conveyed by drinking-water. Some authorities believe that wind can carry the infection for short distances.

Negroes, and perhaps also Chinese, have more or less immunity from yellow fever. Strangers of other races, and especially those from temperate climates, are very liable to attack. They may acquire a considerable and increasing degree of immunity by "acclimatization," but for this it appears to be essential that they reside in a yellow-fever district for some years, including an epidemic period. It is possible that natives gain their immunity in the same way during childhood. Those who have undergone an attack are safest of all. It seems, however, that negroes as well as other persons may lose their immunity by a few years' residence in temperate climates, and even by migration from one yellow-fever district to another. Both susceptibility and severity of attack are found to increase in inverse proportion to the temperature of the native country. In Guiana the case-mortality among West Indians was 7 per cent., Italians and French 17 per cent., English 19 per cent., Germans and Dutch 20 per cent., Scandinavians and Russians 28 per cent. Young and vigorous persons are said to be especially liable to attack, and men more so than women.

Yellow fever follows almost exclusively the lines of maritime traffic, and is not carried far by land. It is certain that ships may become infected and retain the infection with much tenacity, and baggage and other fomites have been known to convey infection without the intervention of infected persons. That a person whether infected or not may carry the infection with him appears to be undoubted, but the most intimate contact with the sick, wearing their unwashed clothes, occupying the same beds, making autopsies, and even inoculating the vomit, may, so it is alleged, fail to impart the disease.

Clinical features. — The incubation period varies greatly, from two or three to fourteen or sixteen days, but rarely exceeds four or five days. The attack is sudden, with high fever and intense headache accompanied by lumbar and spinal pains. Vomiting sets in early, becomes incessant, and in three or four days blood is seen in the vomited matter, and often in the fæces. The urine is albuminous, and scanty or suppressed. Jaundice follows, and the patient passes into a typhoid state. A large proportion of the cases end fatally, the rest in lysis and convalescence in two or three weeks. The duration of the infective period is brief, lasting only the first three or four days of the disease.

Etiology.—The etiology of yellow fever is obscure, and two theories share the chief support: the first is that the disease is due to Sanarelli's *Bacillus icteroides*, the second (and more probable) that it is due to a protozoan parasite conveyed by a species of mosquito.

In 1901 the United States Army Commission reported that whilst *B. icteroides* was not always present in yellow fever, the blood appeared to contain the virus, and retained it after being passed through a Berkefeld filter. The Commission further reported that the disease was not communicable by direct contact, but probably by mosquitoes, as in malaria. The species of mosquito suspected was the common West Indian mosquito, *Stegomyia fasciata* (*S. calopus*). Preventive measures were adopted in Havana on the mosquito hypothesis, with the remarkable result that the disease was stamped out. Guitéras, of Havana, has carried out further experiments which confirm many of the Commission's findings, and, in particular, the transmission of the disease by mosquitoes. A United States Army Expedition reinvestigated the subject in 1902–3, and reported that: (1) Bacterio logical examination of the blood during life, and of organs and blood immediately after death, is negative (2) *Stegomyia fasciata*, when allowed to suck the blood of a yellow-fever patient 41 hours after the onset, can on biting a non-immune person 22 days later produce the disease. (3) *Stegomyia fasciata*, contaminated by sucking the blood of a yellow-fever patient, and then killed, cut into sections and appropriately stained, presents with regularity a protozoan parasite, *Myxo-coccidium stegomyiæ*, which can be traced through a cycle of developments from the gamete to the sporozoit. (4) *Stegomyia fasciata*, fed on the blood of a person with malarial fever, on normal blood, or artificially, does not harbour the myxo-coccidium.

Prevention.—The preventive measures to be adopted against yellow fever are the avoidance of districts in which it is known to prevail, the selection of inland, thinly-populated, and especially elevated points for residence, the systematic destruction of mosquitoes in their breeding-places, the rigid disinfection of infected houses, avoidance of the *Stegomyia* mosquitoes, and strict attention to sanitary conditions. Fatigue, exposure to sun, alcohol, and improper food are said to predispose to infection.

PLAGUE

First introduced from the East, and possibly identical with the Black Death of the Middle Ages (1348), plague was frequently epidemic in England up to the time of the Great Plague in 1665. In the following century it retreated eastward, and disappeared from Europe in 1841 and from Egypt in 1844. In Asia it has lingered on endemically in certain temperate regions, and of late has shown renewed activity, especially in India. Grave epidemics have occurred (from 1896–1913 it caused eight million deaths in India), and infection has been brought in recent years by ship to Great Britain. Since 1894 the disease has assumed some of the characteristics of a pandemic. It is an infectious filth disease, fostered by destitution, uncleanliness, overcrowding, and lack of ventilation.

Clinical features.—There are four chief varieties: the *bubonic* form, the most common and typical, the lymph-glands being chiefly affected in the groin. the axilla, or the neck (carried chiefly from man to man by insects); the *septicæmic*, in which the bacillus reaches the blood; the *pneumonic*, which is spread directly from man to man, and in which the lungs are mainly affected (about 2 per cent. of the cases in India); and *pestis minor*, in which the affection of the glands stops short of the septicæmic stage, and even the local symptoms are slight. There are certain symptoms common to all forms of plague, when at all severe. An ordinary attack of plague usually begins three to five days after infection. Such an attack may develop gradually, but generally there is sudden onset with much fever, as indicated by a high temperature, rapid pulse, headache, backache, hot skin, and thirst. The eyes are injected as if inflamed; the expression, at first haggard, anxious and frightened, becomes subsequently vacant, listless, and dull; the utterance is thick, and the gait unsteady as in one under the influence of alcohol. Mental aberration develops quickly. There is frequently a marked tendency to faint. The tongue is at first covered with a moist white fur, except at the edges, which are red, but later on it becomes dry and of a mahogany colour. Vomiting and nausea are present from the onset. Sleeplessness is a characteristic symptom. The most distinctive sign, however, is the presence of swellings, or "buboes," in the groin, armpit, or neck, which appear on the second or third day of the disease, as large, smooth, tense swellings, painful and tender on pressure, and in size varying from that of an almond to that of an orange.

Cases occur in which these manifestations of the disease are greatly delayed or even absent, as, for instance, in "pneumonic," "gastric," and "septicæmic" plague—forms of the malady which may be mistaken respectively for inflammation of the lungs, typhoid fever, or acute blood poisoning. Plague in these forms is always grave, not only because of the fatality of the cases, but for the reason that they are highly infectious to other persons. It is important, therefore, that, in localities where plague is present or is threatened, cases of anomalous illness of the above sorts should be, without loss of time, brought under medical supervision.

There is also the so-called "ambulant form." In plague of this description the affected person is hardly ill at all, presenting no definite symptoms perhaps beyond indolent, though painful, swellings in groin or armpit. Such plague cases may nevertheless be instrumental in spreading the disease. The case-mortality of plague in India in 1896–1913 was estimated to be not less than 75 per cent.

Bacteriology.—The causal organism, *Bacillus pestis*, was discovered in 1894 by Kitasato in the blood of patients suffering from the disease (Fig. 68). It is a small, round-ended, oval cell, with marked polar staining, hence presenting an appearance not unlike a diplococcus. In the middle there is a clear interspace, and the whole is surrounded with a thick capsule, stained only with difficulty. The organisms are non-motile and often linked together in pairs or even chains (especially in fluid cultures), and exhibit polymorphic forms. In culture the bacillus may be coccal or bacillary in form.

It grows readily on the ordinary media at blood-heat, producing smooth, shining, circular, cream-coloured colonies, with a wavy outline, and these eventually coalesce to form a greyish film. If melted butter (or *ghee*) or oil be added to bouillon, the bacillus grows in "stalactite" form. The following negative characters assist in differentiating the bacillus: There is no growth on potato; milk is not coagulated; gelatin is not liquefied; Gram's method does not stain the bacillus; and there are no spores. The bacillus is readily killed by heat or by desiccation over sulphuric acid. It should be noted that the life of the plague germ (extra-corporeal) in soil and in the floors and walls of houses is of short duration.

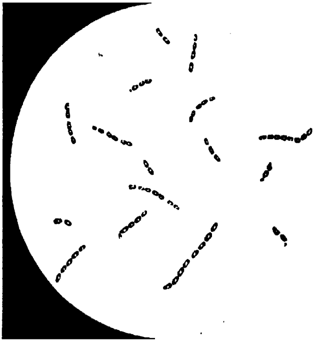

Fig. 68.—Bacillus pestis in chains. × 1,000.
(*Muir and Ritchie.*)

In the body the bacillus chiefly frequents the spleen and lymph-glands, the latter becoming inflamed, especially the inguinal and axillary.

Haffkine has prepared a vaccine which diminishes the incidence and fatality of the disease in inoculated populations, although the degree of protection is not perfect. The vaccine is made from a six-weeks-old broth culture of *B. pestis*, sterilized at 65–70° C. for an hour, and preserved in bottles containing 0·5 per cent. carbolic acid. The dose is 5–10 c.c. Lustig dissolves agar cultures of the bacillus in caustic potash, precipitates the nucleo-proteins, and dries *in vacuo*. The dose is about 3 mg. Haffkine's vaccine has reduced the number of attacks and the mortality. Yersin's serum (60–300 c.c.) may also be used as a prophylactic (5–10 c.c.).

Plague is, in a general sense, a disease of locality. It is contracted principally at night, and, though an infectious disease, the part which man plays as a direct agent is more or less subordinate. The Indian Plague Commission have shown that the essential cause of epidemics is the plague-stricken rat, and the intermediate agent between rat and man and rat and rat is the common rat-flea (*Pulex cheopis*), which acts as a carrier of the bacillus. The common English rat-flea is *Ceratophyllus fasciatus*, and an efficient host of plague germs. The blood of an infected rat generally contains enormous numbers of bacilli, and insects sucking such blood readily become infected, though they may not die of the disease. Rats, which usually suffer from plague before epidemics occur among men, thus convey infection from place to place and from port to port.

Preventive measures, therefore, include the removal of favouring conditions such as filth, polluted soil, vermin, uncleanliness, and overcrowding; the evacuation and vigorous disinfection of infected houses, burning as much as possible; early diagnosis, notification of cases, temporary isolation and observation of "contacts"; the production of artificial immunity by means of inoculation with Haffkine's prophylactic; and the extermination of rats, particularly from occupied buildings, and rendering such dwellings rat-proof. The destruction of rats may be accomplished by various rat traps and poisons (phosphorus, arsenic, bacterial virus, etc.), and on board ship also by pumping CO_2 or SO_2 under pressure.

In 1910 the **L.G.B.** issued Regulations requiring the **S.A.** of any district where there was an unusual mortality among rats to report to the Board and to take measures for the destruction of rats, for removing all harbourage for rats, and for preventing their entrance into buildings. In 1911 the Port of London Authority issued bye-laws for the prevention of an outbreak of plague amongst rats at the docks. Dead bodies of rats should be burnt or buried deeply.

MALARIAL DISEASES

These may conveniently be considered as a single group, although they include many varieties that have received specific names. All have a characteristic tendency to periodicity in the course which the symptoms follow, and this peculiarity is made the basis of a broad subdivision into intermittent and remittent types of fever, the former being the less severe.

Intermittent fever or *ague* is further subdivided into quotidian, tertian, and quartan varieties, according to the length of interval between the attacks, which may occur daily, every second day, or every third day. Each attack is marked by a cold, a hot, and a sweating stage; but the temperature in the intervals always becomes normal. Of these sub-varieties, quotidian ague, with daily attacks, is the most severe, has the longest hot stage and the shortest cold stage, and approaches the most closely to the remittent type.

In remittent fevers there are one or two exacerbations every day, but the temperature during the intervals does not subside to the normal level, nor do the constitutional symptoms entirely disappear. The cold stage is very short and the hot stage protracted. Remittent fevers are met with principally in tropical regions, but are endemic in many marshy districts in Southern Europe, and occasionally spread as far north as the Baltic.

General conditions.—As the intensity of the endemic or epidemic prevalence diminishes, the individual cases tend to assume more and more the intermittent type. Broadly speaking, the tendency to malaria increases with the conditions favouring the presence and increase of the malaria-bearing species of mosquito. A diurnal high range of temperature is one such condition; atmospheric humidity is another. Moisture of the upper part of the soil is an almost invariable condition of malarious districts, and the effect has been said to be heightened by a slight superficial drying. Clay soils, which retain moisture, are among the worst, but chalk or sand or other porous soil may become highly malarious if from any cause the subsoil water is high. Malarious soils almost always contain decomposing vegetable matter in greater or less quantity. In some districts heavy rainfall, especially after long heat and drought, is generally followed by outbreaks of malaria, and irrigation has a similar tendency. They cease to be malarious when the ground is either completely flooded or dried—temporarily or permanently—by drainage and extensive planting (e.g. with *Eucalyptus globulus*). As regards the surface, the prevalence of malaria decreases with the elevation, other things being equal, and if there be a sufficient lowering of temperature. High ground is the most healthy, but exception must be made in respect of spurs of hills and depressions even at high levels, and more particularly of ravines. Among other causes conducive to malaria are abandonment of cultivation, or, on the other hand, the breaking-up of new ground, excavation, or cutting down trees. Fodor concludes from observations at Pesth that only the superficial layers of the soil are concerned in producing conditions favourable to malaria.

Such being the general characteristics of malarious districts as regards climate and soil, it must next be pointed out that they are in themselves inadequate to produce malaria, and also that some of them are entirely wanting in highly malarious localities. Malaria is unknown, for example, in many parts of Ireland, in the Bermudas, and the Pampas of South America, where the physical conditions would a priori appear to be highly favourable. On the other hand, some of the malarious districts in the Deccan and Mysore are steep mountain slopes, and many others in India and elsewhere are equally free from moisture of the soil. Instances are common in which districts, previously healthy, become temporarily or permanently malarious without apparent change in their physical conditions. Malaria being a specific disease, the presence of a specific organism is necessary, and the conditions above described are to be regarded merely as more or less favourable to its growth and to its dissemination by mosquitoes, and especially the latter.

The malaria parasite being a blood parasite, the primary effect of its presence is manifested in the blood, and as a result the disease is characterized by oligocythæmia, marked diminution (10-50 per cent.) of hæmoglobin, anæmia, etc.; the spleen is enlarged and pigmentation occurs. The three pathognomonic signs of malaria are tertian and quartan periodicity, the effect of quinine, and the microscopic examination of the blood.

Etiology of malaria.—In 1880 Laveran first discovered and described parasites in the blood-cells of malarial patients, and on further investigation it was soon found that these assumed many different forms. These differences depend upon the *kind* of fever and the *stage* of fever. The reasons for believing that Laveran's bodies—though they have not yet been cultivated outside the human body—are the specific cause of malaria are (*a*) that the parasites found in the blood of malarial patients of all countries are the same, and such parasites are not found in healthy persons; (*b*) that their development fully accounts for the production of the melanæmia and malarial pigmentations of viscera owing to the melanin-forming property of the parasite; (*c*) that the phases in the development of such parasites correspond with the clinical course of malaria (*Golgi*); (*d*) that quinine, which cures malaria, kills the parasite; and (*e*) that malaria can be conveyed by the introduction of this parasite into the blood of man, and the parasite reappears in the blood of the individual so inoculated. Laveran's bodies have been variously classified as knowledge of them has grown. It is now agreed that these parasites belong to the *Sporozoa*, to the order of *Hæmocytozoa*, and to the genus of *Hæmamœba*.

The malarial parasite as regards man has at least three stages—an *intracorporeal* stage, a *latent* stage

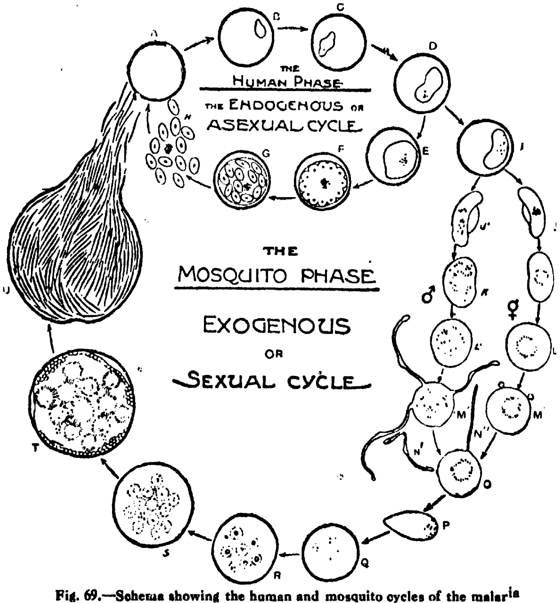

Fig. 69.—Schema showing the human and mosquito cycles of the malaria parasite. Modified from Blanchard's diagram illustrating the life-cycle of Coccidium schubergi. (*From the Malaria Number of the "Practitioner," March*, 1901.)

A, Normal red cell; B, C, D, E, red cells containing amœbulæ or myzopods; F, G, H, sporocytes; I, young gametocyte; J', K', L', M', microgametocytes or male gametes; J'', K'', L'', M'', O, macrogametocytes or female gametes; N', N'', microgametes; P, travelling vermicule; Q, young zygote; R, S, zygotomeres; T, blastophore; U, mature zygote.

(also intracorporeal), and an *extracorporeal* stage (in the mosquito). (Fig. 69.) The parasites gain access to the blood-corpuscles, in which they develop, producing *sporocytes*, which, on the rupture of the corpuscle, become free in the blood and attack other corpuscles passing through the same changes (the cycle of Golgi), and resulting in a fresh generation of spores. The exact characters and changes of the parasite, however, depend partly upon the form of disease (quartan, or benign tertian, or malignant quotidian, i.e. 24-, 48-, or 72-hour fevers), but much more so upon the immediate needs of the parasite, that is to say, whether the development is to be in the human body only and asexual, or in the mosquito and sexual. (*Manson*, *Ross*, and others.) If it is to be the latter, *extracorporeal*, the amœbula does not sporulate in the corpuscle, but becomes a crescent-shaped body absorbing the corpuscle. These crescents, or *gametes*, are of two forms, male and female, and are the first stage in the extracorporeal stage of the life-cycle, that is to say in the mosquito. The male gamete is a hyalin crescent or sphere which develops flagella (*microgametes*) that are of the nature of spermatozoa, and break off from the cell and become free in the blood ingested by the mosquito (Fig. 70). The female crescent, or gamete, is a granular crescent or sphere (*macrogamete*) which starts in the same way as the male form, but becomes spherical and extrudes two polar bodies, receiving at the site of extrusion an impregnation by the free flagellum of the male cell. The result is a *zygote*, a travelling vermicule, which passes into the stomach wall of the mosquito and becomes encysted there, and eventually reproduces spores or *sporozoits*. About the twelfth day it bursts, discharging the reproductive elements into the body cavity of the mosquito, and these, passing from thence, become accumulated in the salivary gland, and are thus in position to be injected into the blood of the next vertebrate bitten by the mosquito. In the human blood again they attack the corpuscles, and recommence the asexual life-cycle. As the *sporocytes* are the means of propagating the parasite in human blood, so the flagellated body (Fig. 70) and sexual cycle are the means of propagation in the mosquito. The temporary disappearance of the parasite from the blood indicates a *latent stage* not fully understood. The different clinical types of malaria are associated with corresponding forms of parasite—the duration of their life-cycles in the body, their morphological characters, and the clinical features to which they give rise.

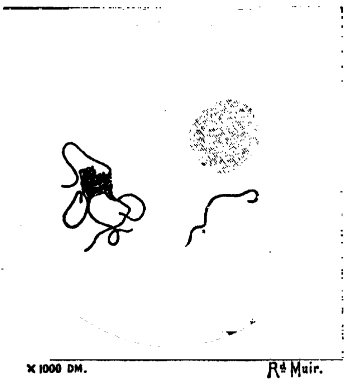

Fig. 70.—Malaria parasite; flagellated body and free-swimming microgamete.

The species of mosquito which has been shown to be the host of the malaria parasite is the *Anopheles*, the body of which is slim, the proboscis long and thick, the palpi long, and the wing "dappled," with dark spots on its anterior margin. It is a "puddle-breeding" insect. The common mosquito, or *Culex*, has short palpi, thick body, thin proboscis, and unspotted wings. It is a "pot-breeding" mosquito. Certain conditions are necessary for the multiplication of malarial mosquitoes, namely, high atmospheric temperature (75–104° F.), collections of water (fresh or brackish), and the presence in the breeding pools of low forms of animal and vegetable life. Many of the physical conditions hitherto cited as favourable to the disease are now seen to be favourable to the specific mosquito, and their relationship to malaria is thus, in part, explained.

The **prevention of malaria** depends upon the fulfilment of four chief requirements: (1) The prevention of mosquito breeding by land-drainage, cultivation, and removal of collections of water; (2) the destruction of mosquitoes (*Anopheles*) and of their eggs, larvæ, and nymphæ; (3) mosquito protection by nets, repellent drugs, house arrangements, etc.; and (4) the use of quinine (6 gr. daily).

RELAPSING FEVER

This fever, known also as "famine fever," or "bilious typhoid," was first recognized clearly in Ireland in the eighteenth century, and still occurs there, although epidemics are not infrequent in Scotland, England, Northern Europe, the Levant, India, and other Eastern countries. There is also an African type of the disease. Epidemics of relapsing fever and typhus may coincide, or one follows the other closely, or sporadic cases of the one are observed during prevalence of the other. Neither climate nor weather has been found to influence relapsing fever in any marked degree, nor has it any apparent relation to soil. Overcrowding and want of food are powerful predisposing causes, especially the latter, which Murchison thought was capable of originating the disease, but many epidemics have occurred without noteworthy privation. The wealthier classes are almost exempt, and females are less susceptible than males. Under favourable conditions it appears in districts that have long been free from it, and in many such cases no history of imported infection can be made out. It has been suggested that the specific agent in Europe may be conveyed by parasites, such as pediculi.

The symptoms include rigor, vomiting, hyperpyrexia, icterus, followed by apyrexia, apparent recovery, and then relapse which alternates with apparent recovery. The disease is highly infectious, but appears to be capable of transport through the air for short distances only, though it readily attaches itself to fomites. A specific spirochæte was discovered by Obermeier (in 1873) in the blood of patients during the febrile stage only, and inoculation with blood containing spirochætes has been found to reproduce the disease in men and monkeys. It is probably communicated by the bite of a tick parasite (hence known as tick fever). The protection afforded by an attack is slight. Only about 5 per cent. of the cases terminate fatally, but convalescence is slow.

LEPROSY

Leprosy is a disease of great antiquity in Egypt, India, China, and Japan. The Biblical term "leprosy" doubtless included many forms of skin disease, and the same ambiguity attends most, if not all, of the other records of the disease in former ages.

Leprosy has been especially confounded with syphilis and elephantiasis arabum, true leprosy being sometimes termed elephantiasis græcorum. It probably made its appearance in Europe about the beginning of the Christian era, and became widely diffused during the next eight or nine centuries. A further increase—attributed by some to the Crusades—took place in the twelfth and thirteenth centuries, but in the fourteenth and fifteenth centuries it began to disappear, and at the present time has vanished from Europe, with the exception of certain limited districts, more especially in Norway, Sweden, Finland, Spain, Portugal, and some parts of Italy, Greece, Turkey, South Russia, and some of the Mediterranean islands, including Sicily and Cyprus. In India in 1901 there were 105,000 lepers. It is prevalent in the West Indies, the west coast of South America, Japan, China, and the greater part of Asia; most of the islands in the Pacific, notably Hawaii; and in many parts of Africa. It is common in Mexico, and minor foci exist in Louisiana, New Brunswick, and British Columbia. Special attention has recently been directed to its increase at the Cape. Districts upon or near the coast are the most frequent seats of endemic leprosy.

In England, special legislation was directed against leprosy in the tenth century, and leper hospitals were established in the eleventh, twelfth, and thirteenth centuries in many of the larger towns. The last record of any extensive prevalence in England was at the end of the seventeenth century, and it is now unknown except as a disease acquired abroad.

Leprosy is diminishing in its few remaining European centres, stationary in the West Indies, Demerara, South Africa, and some other countries, and spreading in the Sandwich Islands and New Caledonia. Chinese immigration is said to have introduced it into North Australia and British Columbia.

General conditions.—Climate would appear to have little influence, since the geographical distribution is or has been almost world-wide, nor has anything been made out definitely in regard to more local meteorological conditions. The effect of season, if any, cannot be traced in a disease which begins insidiously and runs a protracted course. The greater incidence upon coast regions seems to give a clue to the etiology, but the disease prevails in elevated regions far removed from the sea. The use of fish, and especially of decomposing fish, as a principal diet has been credited with contributing largely to the causation of leprosy (*Hutchinson*). This view is supported mainly by the prevalence of the disease in littoral districts, but also to some extent by its frequent appearance in new regions among Chinese settlers, whose skill in cookery enables them to make use of putrid fish, and lastly by its observed disappearance from certain districts where fish diet ceased to be general. On the other hand, there are many inland leprous regions in which fish is rare, or, as in Central China, limited to the use of the wealthier classes. The disease has declined in many localities without any material change in diet, and, further, the vegetarian Brahmins are by no means exempt from leprosy. It would seem, therefore, that a fish dietary, if it has any etiological significance at all, is not operative in all cases. Another hypothesis is that deficiency of common salt in food is conducive to leprosy. Sanitary improvements in the habits and surroundings of the population have, in all probability, been chiefly instrumental in suppressing leprosy in England and elsewhere. Although never confined to the poorer classes, its incidence has been greater upon those living in filthy and unhygienic conditions.

Nothing is known as to any relation with telluric conditions, or transmission by water or air. Negroes, Hottentots, and Chinese are more affected than white races living in the same localities. Males suffer in greater numbers than females, and among the very old and the very young the disease is of rare occurrence.

Authorities are at variance as to the hereditary transmission of leprosy, and very little is known of the way in which the disease is ordinarily acquired. It is communicable by direct or indirect means, from the sick to the healthy, and there is no certain evidence of its arising or spreading in any other way. Hansen states that no sign of leprosy had appeared among the descendants of 160 Norwegian lepers who settled in the United States. Arning has proved it to be inoculable, having successfully inoculated a condemned convict.

Clinical characters.—The incubation period in Arning's case was two years. It is believed to be very variable, extending over months or years, with or without premonitory symptoms. Three chief types are described—(*a*) the anæsthetic (or maculo-anæsthetic), (*b*) the tuberculated or nodular, and (*c*) the mixed. The anæsthetic form causes a destruction of nerve-fibres, and non-sweating, anæsthetic skin patches, with or without pigmentation and bullæ; the tuberculated chiefly affects the skin, resulting in a nodular growth or diffuse infiltration, lepromata, "leontiasis," and marked disfigurement. Mixed leprosy is dependent upon the specific deposit in skin and peripheral nerve trunks. The average duration is given as eight years in anæsthetic and sixteen in skin leprosy, but with wide variations. When the disease commences in early life, its duration is comparatively short. The result is almost always fatal, but it is stated that in Norway 38 cases were cured in the five years 1881–5; and Kaurin believes that, if the disease is localized, early amputation may sometimes permanently arrest it. According to Sand, leprosy may exhaust itself in thirty or forty years if the constitution is exceptionally strong.

Bacteriology.—The *B. lepræ* (Fig. 71) was discovered by Hansen in 1874. It is present in enormous numbers in the skin and tissues, and has a form very similar to *B. tuberculosis*. Spores have not been seen, but Neisser holds that this is the form in which the bacillus gains entrance to the body. The arrangement in clumps and colonies inside the round cells is useful for diagnostic purposes. The bacilli are also found free in the lymphatics, inside connective tissue cells, in the walls of blood-vessels, in the lymphatic glands, and in the internal organs. Bordoni-Uffreduzzi, Carrasquilla (1899), and Campana claim that they have isolated the bacillus and grown it on artificial media, the two former aerobically on peptone-glycerin-blood-serum, at 37° C., and the last-named anaerobically. Cultivated bacteria from the organs of lepers, described rather later by Babés, and still more recently by Czaplewski, differ from the genuine bacillus of leprosy in their incomplete resistance to acids. There is little doubt that the disease is produced by Hansen's bacillus. Bordoni-Uffreduzzi holds that the bacillus has a saprophytic stage in its life-cycle.

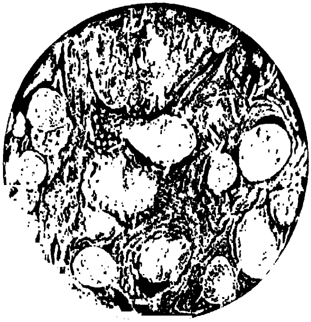

Fig. 71.—Bacillus lepræ. × 1,000. (*Muir and Ritchie.*)

Hansen, Ehlers, and others believe that the disease is spread by contagion; Virchow held the reverse opinion. Besnier and Sticker consider the infection is conveyed in nasal secretion. The Leprosy Commission in India (1890–1) reported that—

(1) Leprosy is a disease *sui generis*; it is not a form of syphilis or tuberculosis, but has striking etiological analogies with the latter. (2) It is not inherited, and has a natural

tendency to die out. (3) Though contagious and inoculable, the extent to which it is propagated by these means is exceedingly small. (4) It is not directly originated by the use of any particular article of food, nor by any climatic or telluric conditions, nor by insanitary surroundings, neither does it peculiarly affect any race or caste. (5) It is indirectly influenced by insanitary surroundings, such as poverty, bad food, or deficient drainage or ventilation, for these increase the susceptibility.

Preventive measures.—The practical suggestions of the Commission for preventive treatment included voluntary isolation of the sick; prohibition of the sale of articles of food by lepers; leper farms and orphanages; and "improved sanitation and good dietetic conditions" generally. Serum-therapy has been attempted, but without success. Up to the present time no curative agent for leprosy has been found.

In Norway, leper asylums were established in 1856, and the number of lepers is believed to have steadily declined. The isolation in these asylums is not rigid, but in Hawaii an island is set apart for the leper settlement, and the seclusion is practically lifelong. It seems clear that the infection is not acquired readily, if we take the ordinary infectious diseases as a standard, and there is some probability that even a partial segregation of lepers may have considerable influence in arresting the disease, assuming that its spread is due mainly to personal intercourse. The difficulties of obtaining a tolerably complete isolation or even registration of lepers are, of course, very considerable.

UNDULANT FEVER

"Malta fever" or "Mediterranean fever" is common along the coast of the Mediterranean and in its islands, and occurs elsewhere. It is a disease of long duration and variable symptoms, including remittent fever (*febris undulans*). Perspiration, pains, swelling of joints, enlargement of the spleen, etc., are among the common signs. The disease simulates typhoid fever. In 1887 Bruce cultivated from the spleen the *Micrococcus melitensis*, a small, round, or slightly oval coccus, occurring singly, in pairs, or in chains. It can be cultivated from the spleen, on agar at 37° C.; colonies appear about the third day as small, round, slightly raised growths; old cultures assume a buff tint. The organism is present in the peripheral blood in all cases during the early stages of the disease, and in severe pyrexial relapses. It has been isolated from the urine, and occurs in great abundance in the milk and urine of apparently healthy goats and cows. The disease is transmissible to man by the medium of milk from infected goats.

PELLAGRA

Is a widely distributed disease in Southern Europe and elsewhere, of long duration, characterized by a peculiar rash, not unlike a severe sunburn, which appears on the face, round the neck, and on the back of the hands and feet. This eruption recurs each year at determinate seasons (spring and autumn); it appears suddenly under the influence of exposure to sunlight, stands out some days, then fades off gradually, and is followed by long persistent desquamation and roughness of skin. Together with the eruption other symptoms appear. They are irregular fever, frequent fits of giddiness, debility, confusion of mind, salivation, scurvy, insomnia, pyrosis, and diarrhœa. These symptoms abate during the summer months and disappear almost entirely in winter, especially in early cases. They return with the rash each spring. After a period of progressive aggravation, which may last three, five, or thirty years, the patient becomes leprotic, emaciated, partly paralysed, and entirely demented. The disease affects the agricultural classes almost exclusively. Until recently the disease was held to be due to the use of maize, which was believed to convey germs, toxins, or other poisons. Sambon has suggested that pellagra belongs to the protozoal group of diseases and is transmitted by sand-flies (*Simulidæ*) near infested streams.

TRYPANOSOMIASIS

Morbid conditions produced by trypanosomata in man include chronic fever, skin eruptions, etc., of which *sleeping sickness* may be regarded as the terminal stage. Trypanosoma infection is probably caused by the entrance into the blood, and thence into the cerebro-spinal fluid, of a species, *Trypanosoma gambiense* (p. 340), which is transmitted from the sick to the healthy by a tsetse-fly, *Glossina palpalis* (Fig. 72), and, apparently, by it alone. It has been demonstrated by experiment that not only were these flies, fed on sleeping-sickness cases, capable of conveying the disease to healthy monkeys, but that freshly caught flies from an infected area, without any artificial feeding, were also capable of conveying the disease. This fly, like its congener the tsetse-fly of South Africa, is confined to well-defined areas, which correspond absolutely with the distribution of sleeping sickness; whereas, in regions where no *Glossina palpalis* is found, although other biting flies abound, there is no sleeping sickness. While a large percentage of the inhabitants of the sleeping-sickness areas have the trypanosome in their blood, in not a single inhabitant of non-sleeping-sickness areas was this parasite found. Monkeys inoculated with cerebro-spinal

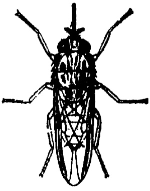

Fig. 72.—Tsetse-fly.

fluid from sleeping-sickness patients, or with blood from natives not as yet showing symptoms of sleeping sickness, but containing a similar parasite, sickened and died with all the symptoms of sleeping sickness. As in the case of ankylostoma, individuals may have this trypanosome in their blood and yet reveal no symptoms of the disease. A Portuguese Commission laid emphasis upon a diplostreptococcus which a number of observers have found to be present.

The disease has spread in the Congo region, Uganda, and northwards along lines of communication—that is, rivers—and has become a scourge in certain riverine tribes. Clinically the early stage of sleeping sickness may be recognized by profound debility, irregular fever, papular and pustular eruptions, annular erythema, the enlargement of the cervical glands (polyadenitis), enlargement of the spleen, œdema, and certain pathological conditions of the blood, including lymphocytosis. Sleeping sickness, acute or chronic, is the concluding stage before death.

DYSENTERY

Clinically, dysentery takes various forms according to the chief character of the intestinal lesion, e.g. catarrhal, ulcerative, fulminating, relapsing, recurring, chronic, gangrenous, hæmorrhagic. The leading symptoms are griping, tenesmus, and muco-sanguineous stools. Three factors are concerned in the production of the disease : (*a*) influences that weaken the bowels, (*b*) specific germs or parasites, and (*c*) the ordinary bacteria of suppuration. Three types of dysentery are now recognized : (1) Endemic, amœbic, or protozoal dysentery, due to *Amœbæ* (p. 338), *Balantidium coli*, the Bilharzia, or the parasites of kala-azar and malaria. Amœbic dysentery is now held to be caused by the *Entamœba hystolytica*. (2) Epidemic dysentery, due to *Bacillus dysenteriæ* (Shiga or Flexner types) or other bacteria. (3) Verminous dysentery, set up by *Schistosomata.* The germs of dysentery are often water-borne, but may be conveyed by flies, dust, and human carriers. Lowered vitality is predisposing. Mott holds that "asylum dysentery" is identical with tropical dysentery.

The disease is not confined to tropical climates. At one time it was "one of the most prevalent and fatal diseases of London" (*Baly*). It is believed to be influenced by season and soil, autumn and polluted subsoil favouring its occurrence, though personal predisposing conditions doubtless play an important part. From a sanitary point of view, water supply, dietary, and uncleanliness are the conditions into which inquiry should be made. It is probable that the excreta serve as one of the chief media of infection, and they should therefore be disinfected. Apart from institutional outbreaks (e.g. asylum dysentery), dysentery is a comparatively rare disease in this country.

BERI-BERI

Is endemic in Western India, in the Indian Archipelago, China, and Japan. It is mostly confined to the working classes, and is said to be due to an organism or mould mixed with or infecting stale white rice, or to over-milled rice which has lost its pericarp and is thus deficient in phosphorus. Others consider it a "place disease" or a "disease of deficiency," and Durham holds that it is more a "gang" or "institutional" disease. It is a kind of communicable scurvy of the tropics, affecting the underfed, and is characterized by weakness, partial paraplegia, dropsical distension of the abdomen, limbs, and face, and many of the features of alcoholic neuritis. The disease may be communicated from person to person directly or through fomites, or it may be due to community of deficient diet.

Black Water Fever

Is characterized by pyrexia following a rigor, bilious vomiting, icterus, hæmoglobinuria, and frequently suppression of urine. The distribution is wide and endemicity is limited to low, swampy grounds. The etiology is not yet determined. There are three theories, attributing it respectively to malaria, quinine, and hæmoprotozoa.

Kala-azar (Burdwan Fever)

This is a chronic infective disease with irregular fever, enlargement of spleen, anæmia, and the presence of "Leishman bodies," a species of *Herpetomonas* (Fig. 73). An epidemic occurred in Assam in 1870, and various sporadic cases have been described. **Oriental sore** (Delhi boil) may be due to the same cause.

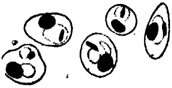

Fig. 73.—Kala-azar parasites from the spleen.

Dengue

This disease was first recognized during outbreaks in Farther India in 1824, and in the West Indies, Mexico, and the Southern States in 1827-8. Dengue resembles influenza in the intensity of its epidemics, which often affect almost every person in a town. It spreads mainly along lines of traffic. Even in tropical countries its prevalence is greatest in the hot season, and elsewhere it occurs only in summer and autumn, and in years of high temperatures. It affects maritime towns, and rarely spreads inland. Low-lying, filthy and overcrowded quarters are the first to be attacked. After a short incubation of two to four days the onset is sudden, with rigors, pyrexia, and acute pains and tenderness in the small joints of the hand and feet. Very soon the large joints become affected, then the bones and muscles, and the head and back. A transient erythema appears at this stage in half the cases. In one or two days a remission or intermission of all the symptoms occurs after profuse sweats having a pungent odour, but after a short interval the symptoms return in a modified degree, often accompanied by glandular swellings, and a rubeolous rash, which as a rule consists of irregular red elevated spots. The second febrile stage passes off in three or four days at longest, and slow desquamation and convalescence follow. Dengue is fatal only in debilitated persons, or in the very young or old. In some epidemics the disease has apparently attacked cattle, dogs, and cats. It is believed to be caused by a germ or amœba conveyed by mosquitoes.

CHAPTER XV

PREVENTION OF INFECTIOUS DISEASES

In the preceding chapters reference has been made to the various means by which specific and other diseases are disseminated or checked. It remains to consider the powers and duties of the Sanitary Authority (**S.A.**) and of the Medical Officer of Health (**M.O.H.**) in relation to preventable diseases, and especially infectious diseases. All infectious diseases may be said to be preventable, but not all are amenable to the preventive measures which at present can be enforced by the most active sanitary administration. Smallpox and rabies may be taken as types of specific diseases which can be and ought to be suppressed, and are now, as a matter of fact, limited to such persons and such populations as do not choose to adopt the measures which reiterated experience has shown to afford safety. Measles and whooping-cough, on the other hand, although strictly speaking preventable diseases, always dependent (so far as we know) upon direct or indirect infection from other cases, have not yet been brought under control. No prophylaxis has been discovered, and, as infants are especially liable, the susceptibility of the population is speedily renewed, even after an outbreak. Isolation and disinfection are theoretically capable of arresting the spread of these diseases if applied in every case and at the commencement of the infectious stage, but in practice this can scarcely be accomplished at present, for reasons that will be stated later.

Scarlet fever, diphtheria, and enteric fever are examples of a different class. They are not entirely dependent upon infection from person to person, but are affected by a variety of conditions of which every year brings us fuller knowledge. Some of these conditions, including personal infection, infection from lower animals (by consumption of milk or flesh, or in other ways), and infection by drinking-water, are more or less under our control. So, too, are the various "insanitary conditions" which conduce to the spread and malignancy of specific diseases, and telluric conditions also are to a great extent remediable. Experience has shown that, if carried out thoroughly, isolation, disinfection, and quarantine can very greatly reduce the incidence of these diseases, but there is always danger from unrecognized cases, from the early stages of the disease before the diagnosis is made, from importation of infection, and from accidental or wilful neglect of precautions. It must also be remembered that there may be modes of infection in these diseases at present unknown to us, and this is especially probable in respect to diphtheria. By way of summary it may be said that, in addition to improved sanitation, the chief means of prevention are (*a*) notification, (*b*) isolation and quarantine, (*c*) disinfection, (*d*) prophylactic inoculation (vaccines and antitoxins), and (*e*) the adoption of special measures in particular diseases.

Compulsory notification of certain infectious diseases rests in London upon the Public Health (London) Act, 1891, and elsewhere upon the Infectious Diseases (Notification) Act of 1889, as amended by the Infectious Diseases (Notification) Extension Act of 1899 (which also enables any **S.A.** with the sanction of the **L.G.B.** to add temporarily or otherwise other infectious diseases to those scheduled in the Act). From time to time the **L.G.B.** issues special Regulations and Orders for the notification of additional diseases. At the time of writing (1917) the **notifiable diseases** are smallpox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus, enteric fever, relapsing fever, continued fever, puerperal fever. all forms of tuberculosis, cerebro-spinal fever, acute poliomyelitis, ophthalmia neonatorum,* and measles (including German measles).† The inclusion of membranous croup in the list tends to make the reporting of diphtheria more complete, and "continued fever" covers obscure cases of enteric fever, or possibly typhus. A large number of trivial cases are reported as erysipelas, but the disease has practical importance in connexion with vaccination and puerperal fever. Doubt having arisen as to the meaning to be attached to "puerperal fever," the Royal College of Physicians expressed the opinion that it should be understood to include "septicæmia, pyæmia, septic peritonitis, septic metritis, and other septic inflammations in the pelvis occurring as the direct result of childbirth."

Certain minor diseases, such as chickenpox, may be made notifiable temporarily or otherwise in order to ensure detection of more serious complaints such as smallpox. In 1908 the **L.G.B.** approved of the extension of the Notification Act, 1899, to glanders, anthrax, and hydrophobia in man, in areas where these diseases were prevalent. In times of imported epidemic, plague, cholera, or yellow fever would be temporarily notifiable.

Forms of certificate are supplied to every practitioner practising in the district, and a fee of 1s. is paid to him for each certificate regarding a private patient and 1s. for each case in public practice. "Every medical practitioner attending on, or called in to visit, the patient shall *forthwith*, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the **M.O.H.** for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering." The penalty for default is a fine not exceeding 40s. Under the same penalty the householder is compelled to notify, but in a less formal way, and without receiving any fee. The Act applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation," but not to any "hospital in which persons suffering from an infectious disease are received." It gives no power of compulsory removal of patients to hospital, nor even power of entering upon the premises for the purpose of making inquiries, but it is very rarely that any difficulty is met with in the latter respect.

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* Duty of notification placed on midwife as well as on medical practitioner.

† Duty of notification placed on parent or guardian as well as on medical practitioner.

Among the advantages to be derived by the **M.O.H.** from compulsory notification are the following :—

1. Early and complete knowledge of all the cases of notifiable disease, and thus of the whole prevalence and distribution in the district. Death-returns give only a small fraction of the cases, and after an interval of many days or weeks.

2. Power to exercise such supervision as may be necessary over every case during its whole course, and to enforce due observance of the provisions of the Public Health Act as regards isolation and disinfection. This has special importance in connexion with outbreaks of scarlet fever, diphtheria, or enteric fever in dairies, schools, etc.

3. Opportunity of offering, and in some cases compelling (*see* p. 596), removal to hospital in every suitable case, unless the **S.A.** has failed to provide hospital accommodation. Vaccination can be offered, and is rarely refused, in households invaded by smallpox.

4. Opportunity to detect and supervise "contacts" and "carriers."

5. Opportunity of investigating the sanitary conditions of

all households in which cases of enteric fever, or diphtheria, or other notified disease may occur.

6. Power to control the spread of infection through schools or other centres, by excluding members of infected households.

7. Means of detecting at once any suspicious grouping of cases around schools, milk supplies, water supplies, or other common foci. A comparison of the data obtained by the routine inquiries into each notified case will at once reveal this, although there may be nothing in any single case to arouse the suspicions of the friends or of the medical attendant.

Notifications for 1916.—During 1916 the total number of cases of the chief notifiable diseases in England and Wales, including cases in ports but excluding cases among sailors and soldiers, was as follows :—

Disease.	England and Wales, 1916.	
	No. of cases notified.	Rate per 1,000 of population.
Tuberculosis (pulmonary)	72,479	2·10
,, (other forms)	28,777	0·69
Smallpox	149	0·00
Typhus fever	4	0·00
Scarlet fever	75,722	2·19
Diphtheria	51,707	1·50
Enteric fever	5,564	0·16
Continued fever	82	0·00
Relapsing fever	—	—
Puerperal fever	1,996	0·06
Erysipelas	18,510	0·54
Cerebro-spinal fever	1,306	0·04
Poliomyelitis	689	0·02
Cholera	—	—
Plague	12	0·00
Ophthalmia neonatorum	7,618	9·69*
Measles and German measles	348,090	10·09

* Rate per 1,000 births.

In a number of towns it has been found possible, with the aid of notification, to isolate in hospital all the cases of smallpox, and three-quarters, or more, of the scarlet fever, and to establish a cordon of vaccination around each new smallpox centre.

Epidemic prevalence of disease is determined by many causes, of which some are still unknown to us, and others (including climatic conditions) are beyond human control. Nevertheless, the known and preventable causes, such as the transmission of infection from person to person, or by means of milk, water, flies, etc., are factors of the utmost importance, and it is safe to affirm that, however great or however small may be the total number of victims, the suppression of known and preventable favouring conditions renders the danger less than it would otherwise have been. Individuals may be saved, and widespread outbreaks delayed, restricted, or averted.

Notification of measles.—Among the diseases recently made notifiable are measles and German measles. It must be borne in mind that the utility of notification in measles is limited, for the following reasons: (1) Medical advice is frequently not taken in mild forms of the disease. (2) It is largely a contact disease, which has no relation to water or milk supplies, or to defects of drainage. (3) There is no vaccination. Isolation, disinfection, and improved nursing are, therefore, the chief preventive measures which can be brought to bear against measles, even if it be possible to obtain complete notification. Isolation in the homes of the poor is impracticable, and isolation in hospitals would entail a formidable addition to their present size. The results of isolation also are less likely to be satisfactory in measles than in scarlet fever, and, as a very large proportion of the sufferers are infants, there would be great reluctance on the part of parents to consent to removal. (4) Infection begins generally at least three days before the rash appears. (5) There is a long incubation period, which adds to the difficulty. (6) Lastly, measles is often so widespread that few susceptible children among the working-classes escape, and measures of prevention involve very comprehensive undertakings.

On the other hand, valuable information is derived from notification of measles, and from this point of view its inclusion in the schedule of notified diseases is important. Even an incomplete notification is invaluable in rendering possible early control over school-infection; further, hospital isolation of measles would no longer appear impracticable if epidemics were not allowed to proceed unchecked; and, lastly, notification of measles brings to light many cases of scarlet fever which, in the absence of any medical control, are regarded by the parents as "only measles." This last argument applies also to the notification of Rötheln and of chickenpox.

Public Health (Tuberculosis) Regulations, 1912 (repealing similar Regulations issued in 1908-11), provide for the notification within forty-eight hours of all forms of tuberculosis to the local **M.O.H.** Weekly lists of children suffering from this disease must be sent by the school medical inspector to the local **M.O.H.**, and similar lists by the medical officer of a poor-law institution of patients so suffering admitted or discharged. Notification must not be made on a diagnosis derived solely from tuberculin tests. Every local **M.O.H.** must keep a register of full particulars of such notification, and furnish the **M.O.H.** of the county weekly with a list of such notifications. The duty of investigation of the source of infection and providing means of prevention is also included, and power is given to a local Authority to assist medical practitioners in diagnosis and prevention.

Public Health (Ophthalmia Neonatorum) Regulations, 1914, provide for the notification of this disease by the medical practitioner (with name and address of parent or guardian and the date of onset of the disease) or the certified midwife. In 70 per cent. of the cases of ophthalmia neonatorum the infection is due to the gonococcus, contracted during parturition or by subsequent infection from the mother.' Suppuration and ulceration of the cornea may follow. In 1,100 cases of blindness examined by Harman, 24 per cent. were due to gonorrhœal ophthalmia.

Investigation of epidemic disease.—System, method, and thoroughness are necessary in epidemiological inquiries, and it is essential to attack problems of disease in an organized way—general, particular, and personal (local registers).

1. **General inquiry** will follow well-recognized lines :

(*a*) General sanitary conditions, circumstances, and topography of the area. This includes the essential facts of housing, water supply, drainage and sewerage, refuse disposal, cowsheds, dairies, and slaughter-houses, food supply, schools, industries, etc.

(*b*) Local sanitary administration staff facilities and accommodation for preventive medicine, local Acts, bye-laws and regulations.

(*c*) Brief history of epidemic and endemic disease in area, sickness- and mortality-rates.

(*d*) Investigation of particular outbreak — its history, incidence, character, channels of infection, causation, bacteriological and chemical reports, and observations as to contacts and carriers.

(*e*) Measures taken or proposed — notification, isolation, disinfection, special measures.

2. **Particular inquiry.**—The Regulations of the **L.G.B.** require that upon receiving information of any outbreak of dangerous infectious disease the **M.O.H.** shall at once make full inquiries, and adopt such precautionary measures as he may consider requisite. The necessary inquiries and investigations are simplified and made more systematic by the use of printed forms with spaces for the insertion of the details for each notifiable disease. Those used for scarlet fever, enteric fever, and diphtheria should give prominence to the details of milk supply and other channels of infection.

The following inquiries should be made in all cases :—

1. *Patient.*—Address, name, sex, age, date of onset, date of rash, present and past isolation, probable source of infection, recent contact with infected persons or things.

2. *Household* (including patient).—Sex and age of each inmate, susceptibility (as shown by history as to previous attack), date of previous attack (if any), occupation, place of work or school, and date of last attendance thereat.

3. *Work or business carried on in the house.*

4. *Water supply* and *milk supply.*

5. *Sanitary condition* of premises and surroundings.

6. *Previous cases* of the disease, or of conditions allied to it or simulating it in the home or in the vicinity, or at the school or workplace.

7. *Possible sources of infection.*—(1) Visits; (2) visitors; (3) place of work; (4) food, milk, ice cream, shell-fish, watercress, etc.—what, when, where purchased, condition; (5) water; (6) previous cases of sick headache, sore throat,

or diarrhœa in the house or neighbourhood; (7) school, including Sundays; (8) drain nuisances, at or near house; (9) tailoring, washing, mangling; (10) contacts or carriers; (11) animals and insects; (12) social habits and practices.

In dealing with an outbreak of smallpox, further inquiry must be made regarding the condition of each individual as to vaccination and revaccination, noting the dates.

In enteric and diphtheria cases note should be taken of the previous state of health of the patient, the duration of his residence in the house, and the occurrence of any sickness among domestic animals.

The precautionary measures to be enjoined, and if necessary enforced, will vary with the nature of the disease and the circumstances of each individual case.

3. **Local registers of sickness.**—From the report sheets more important details can be entered in registers, a process which involves very little cost of trouble and time, and gives a comprehensive view of the facts that cannot be attained in any other way. Each disease should have its separate register, the columns of which may be headed as follows:—

No.
District.
Address.
Name of patient.
Occupation.
Sex.
Age.
Date of onset.
,, ,, notification.
,, ,, receipt of ditto.
,, ,, removal to hospital.
,, ,, disinfection.
Result, and date of recovery or death.
Place of work or school.
Date of last attendance at ditto.
Milk supply.
Water supply.
Sanitary notes.
Reference to other cases.
Other cases in household.
Medical attendant.
General notes, as to precautions, history, etc.
(Vaccination: date and condition.)

If such registers are kept systematically, any suspicious grouping of cases in any given locality, or in connexion with any particular water supply, milk supply, school, or workplace, cannot fail to attract attention at once.

Disease maps.—Maps showing the distribution of disease according to locality can be readily prepared from the information given in the report sheets or registers. A large-scale map is needed for crowded districts. Each disease being represented by a particular colour, a spot of this colour or a coloured pin is placed on every house invaded by the disease in question. Each map may serve for one or more diseases, and for a whole year, or such shorter time as may be determined.

Isolation of the patient.—Hospital isolation should be urged in all cases where practicable, and can be enforced under the conditions specified in the Public Health Act, 1875, s. 124, and the Public Health (London) Act, 1891, ss. 66 and 67. Much may be done by persuasion, by pointing out the benefit to be derived by the patient as regards nursing, food, and greater liberty during convalescence, and by explaining the protracted course of the disease, the risk of infection, and the inconvenience or impossibility of maintaining due isolation at home. There will rarely be much difficulty in removing smallpox cases.

Failing removal to hospital, the arrangements for **home isolation** must be made as complete as possible, but in an ordinary working-class household due isolation is usually impracticable. In large households it may be possible to obtain complete isolation and to maintain it throughout the illness upon the lines indicated below.

1. *Arrangement of the sick-room.*—The patient should be kept in one or two rooms, preferably at the top of the house, or in a detached wing, exclusively set apart for his use. A fire should be kept burning for the sake of free and effective ventilation and destroying waste material, even when not required for heating purposes. No one except the persons in actual charge of the patient should be allowed to enter the room. No one should leave the

room without washing hands and changing outer garments, or an adjoining room may be used for this purpose. No food should be taken out of the sick-room, nor any clothing or utensils, without previous disinfection. The "barrier" system of nursing infectious cases should be adopted (*see* p. 271).

2. *Disinfection during the illness.*—A plentiful supply of 1-in-1,000 mercuric chloride solution (or 10-per-cent. carbolic solution) should be provided. Disinfection of excreta and secretions may be attempted by adding an equal bulk of the solution, which may with advantage be placed in the vessel before receiving the excreta. In enteric and cholera the evacuations should not be put in privies or places where they may infect others. Old linen should be used in place of pocket-handkerchiefs, and after use thrown into the fire. Linen, etc., requiring washing should be placed in a large vessel filled with the disinfectant solution; such articles should subsequently be rinsed in water before washing, to remove the disinfectant. All utensils should be similarly disinfected before leaving the room.

3. *Final disinfection at the end of the case.*—(*a*) All linen, cotton, and silk articles which can be removed should be boiled for ten minutes, but exception may be made in respect of certain dyed fabrics and other special articles; (*b*) all movable textile materials which cannot be boiled—including blankets and other woollen materials, beds, pillows, mattresses (not, of course, spring mattresses), curtains, hangings, carpets, rugs, etc.—must be removed and disinfected by steam; (*c*) the remaining articles must be laid as open as possible, and the room fumigated by sulphurous acid, formaldehyde, or chlorine; (*d*) all furniture and other movable articles should be taken out into the open air, and brushed, washed, or beaten; (*e*) the walls, ceiling, floor, and all surfaces must be cleansed, sprayed, or

washed, special attention being given to crevices and corners. It is an additional safeguard to strip off the paper, and to limewash the ceiling and walls.

In the event of death taking place from an infectious disease, the body should as soon as possible be placed in a coffin with chlorinated lime or other suitable disinfectant, and should be buried (or cremated) with no longer delay than is necessary to allow the fact of death to be verified. Holding of "wakes," large funeral assemblages, and exposure of the corpse to visitors are especially to be avoided, as is also borrowing of mourning dress for the occasion of the funeral. (*See also* **L.G.B.** Memorandum, 1905.)

Disinfection should always be carried out under the direction of the sanitary staff at the end of the case, but disinfectants may be supplied gratuitously by the **S.A.** for use during the illness. Clothing and all movable articles should either be boiled at home, or removed to a disinfecting station and treated by steam or hot air; rooms, and articles that cannot be removed, should be disinfected in the manner described.

When the patient is removed to hospital the premises may be disinfected at once, but the occurrence of any later case will, of course, necessitate a repetition of the process.

Home cases offer more difficulty. The final disinfection cannot usefully take place until after the end of the infectious stage, as determined by the written certificate of the medical attendant or the judgment of the **M.O.H.** It is desirable, in order to prevent misunderstanding, to fix a minimum interval between onset and final disinfection, which in scarlet fever should not be less than six weeks, and to explain this and the reasons for it upon the printed notices left at the house.

Sanitary defects must be remedied, and any clue or even suspicion as to milk or water infection must be followed up at once. It may be necessary to communicate with employers or other persons, if there is reason to anticipate neglect of due precautions against conveying infection.

In outbreaks of smallpox it is necessary to provide for immediate vaccination or revaccination, and to urge it not only upon the inmates of the infected house, but also on all who have been in contact with the patient, and on his neighbours and fellow-workmen.

Quarantine.—If the patient is removed to hospital and disinfection properly carried out, it is only necessary to keep the household under observation for the maximum period of incubation of the disease in question. If the case is treated at home, the household must be kept under a certain degree of quarantine until the last case has ceased to be infectious and the final disinfection has been completed.

During the quarantine period no children from the house should be allowed to attend school, but this restriction may be relaxed if the case is one of enteric fever. The same exclusion should be insisted upon as regards certain occupations, notably milk traffic, nursing, washing, and businesses involving the handling of food; and this is especially important when the work in question is carried on in the house. Tailoring and all forms of seamstress's homework should be forbidden. Strict injunctions should be given against admitting persons, especially children, into the infected house, but there is no power to enforce this bye-law, or to inflict punishment in case of default. Exposure of infected persons or articles in any public place is, however, dealt with under s. 126 of the Public Health Act, 1875, and s. 68 of the London Act, 1891. As regards smallpox, the quarantine should be rigidly enforced, and no member of an infected household should be allowed to follow his business until the period of danger is over.

QUARANTINE TABLE

	Usual incubation period (in days).	*Period of quarantine required after* latest *exposure to infection (in days).*	*Usual period of infection ceases.*
Asiatic cholera .	3 to 6	12	Seven days from complete cessation of diarrhœa. Carriers occur.
Chickenpox . .	10 to 16	20	When every scab has fallen off.
Diphtheria . . .	2 to 10	12	In 4 weeks, if no discharges and no albumin, and if bacteriological examination of nose and throat be negative.
Erysipelas . . .	3 to 10	12	When rash gone and desquamation ceased.
German measles (Röthein)	7 to 18	20	In not less than 10 days from appearance of rash.
Influenza . . .	1 to 4	5	In 3 days after temperature has become normal, and all catarrhal discharges have ceased.
Measles	10 to 14	16	In not less than 2 weeks from appearance of rash.
Mumps	10 to 22	24	In not less than 3 weeks, and then only when 1 week has elapsed since subsidence of all swelling.
Plague	2 to 8	21	In 1 month.
Puerperal fever .	3 to 5	—	When discharge stops.
Scarlet fever . .	3-5 (1-8)	10	When desquamation, sore throat, and albuminuria disappear, but never in less than 6 weeks.
Smallpox . . .	12 to 14	16	When every scab has disappeared.
Typhoid fever .	7 to 21, usually 10 to 14	23	Indefinite (typhoid carriers).
Typhus	5 to 14	14	After 4 weeks.
Whooping-cough .	7 to 14	21	In 5 weeks from commencement, provided all characteristic spasmodic cough and whooping have ceased for at least 2 weeks.
Yellow fever . .	3 to 6	15	— —

In some towns quarantine stations are provided, and are usually attached to the isolation hospitals.

The sick person having been removed to hospital, free lodging is offered to the rest of the household during the quarantine period, and meanwhile the house and its contents are thoroughly disinfected. This plan has been adopted in many towns in cases of smallpox, and its utility is obvious.

In all these matters, and especially in the removal of the patient to hospital, due consideration should be given to the opinion and advice of the medical attendant by whom the case has been notified.

Cautionary and advisory notices may be left at the house, explaining in simple language the precautions that are necessary, and the penalties attending neglect of them. Such leaflets should include directions as to isolation and disinfection, and instruction to report immediately any further cases. It is convenient also to leave a post-card addressed to the **M.O.H.**, to be signed by the medical attendant when, in his judgment, the period of infection is at an end, and final disinfection of the premises is needed.

Quarantine, in the original sense, is not observed in this country. The special precautions directed against the importation of infection from abroad are those set forth in the **L.G.B.** Order of September 9th, 1907, summarized below.

Regulations as to cholera, yellow fever, and plague.—The Customs Officer, who is the first to board the ship, must as far as possible ascertain whether it is "infected" or "suspected," and if he has reason to believe that it is, or that it has come from an infected port, he must obtain from the master (or from the surgeon if there be one) a written statement in prescribed form declaring the occurrence or non-occurrence of cases or suspected cases during the voyage. If he finds the ship to be infected he must order the master to anchor, and must give notice to the **S.A.** of the port at which the ship is about to call.

If from such warning, or from other information, the **M.O.H.** has reason to believe that any ship within the jurisdiction of his **S.A.** is "infected" or "suspected," he must forthwith visit and examine it; and *may* do so if it comes from an infected port. If he finds that there is or has been a case (of one of the three diseases in question) on board, he must certify accordingly to the master, who is thereupon bound to moor in the place appointed. The **M.O.H.** must then examine every person on board, none being allowed to leave the ship until the examination is made. All who are found to be suffering from such disease are to be removed to the hospital or place provided by the **S.A.**, if their condition admit of it, and must not leave such place until the **M.O.H.** certifies that they are free from the disease. If they cannot be removed, the ship remains subject to the control of the **M.O.H.**, without whose written consent the infected persons cannot leave the ship. Persons certified by the **M.O.H.** to be suffering from an illness which he suspects may prove to be one of the three, may be detained either on the ship or in some place provided by the **S.A.**, for not more than two days, in order that it may be ascertained whether their illness is or is not of the kind suspected. No person, not certified as above, is to be permitted to land, unless he satisfies the **M.O.H.** as to his name, place of destination, and address at such place; and the **M.O.H.** must give such names and addresses to the clerk of the **S.A.**, who must transmit them to the **S.A.** of the districts in question. The **M.O.H.** must give directions and take such steps as may appear to him to be necessary for preventing the spread of infection, and the master of the ship must carry out such directions as are given to him. In the event of a case ending fatally on board, the master must, at the direction of the **S.A.**, either bury the body at sea, properly weighted, or deliver it to the **S.A.** for interment. He must disinfect, and if necessary destroy, the clothing, bedding, and other articles of personal use likely to retain infection, which have been used by infected persons; and disinfect the ship, and disinfect or destroy all articles therein probably infected, according to the directions of the **M.O.H.** If he believes the ship to be infected, or to come from an infected port, the **M.O.H.** may order the bilge water and water ballast to be pumped out before the ship enters dock; or may cause the water-ballast tanks to be sealed, if emptying them would endanger the ship. He may order all casks or tanks containing drinking-water to be emptied and cleansed, on the **S.A.** providing a proper supply.

Where a vessel is not infected, but has passengers on board who are in a filthy or otherwise unwholesome condition, the **M.O.H.** may certify to the master that in his opinion it is desirable, with a view to checking the introduction or spread of cholera, yellow fever, or plague, that no persons should be allowed to land until they have satisfied him as to their names and places of destination, and addresses at such places. Thereupon the same measures are to be adopted as in case of persons permitted to leave an infected ship.

The master of a ship "infected" with plague or "suspected" of it shall, under the direction of the M.O.H., employ suitable means for the effectual destruction of rats. The same applies to ships coming from plague-infected ports, or those upon which there has been an unusual mortality among rats. In ships "infected" by yellow fever, or "suspected" of it, or which have come from parts infected with that disease, the master shall effectually destroy mosquitoes and their larvæ to the satisfaction of the M.O.H., who shall certify the action taken.

The master of an "infected" or "suspected" ship must hoist at the mast-head a large yellow and black flag, borne quarterly, when the ship is within three miles of the coast of England and Wales, and at night, at a height of not less than 20 feet above the hull of the ship, a signal of three lights in triangular form, 6 ft. apart, the top light white and the two lights at the base red in colour.

The expression "infected ship" means a ship which at the time of its arrival from a foreign port has on board a case of cholera, yellow fever, or plague, or which has had on board a case of cholera or plague within a period of seven days, or of yellow fever within a period of eighteen days, prior to that time. The expression "suspected ship" means a ship which has had on board during the voyage, or during the stay of the ship in the port of departure, or in a port in the course of the voyage, a case of cholera, yellow fever, or plague, but which has not had on board a fresh case of cholera or plague within a period of seven days or of yellow fever within a period of eighteen days prior to the time of its arrival from a foreign port.

The **L.G.B.** have from time to time issued and revoked Orders of a similar nature to the above, both for ships coming foreign and for outward-bound and coasting ships, under powers conferred on the Board by the Public Health Acts 1875, 1891, 1896, and 1904. They also issue to **M.O.H.** of port and riparian **S.A.** concerned, periodical statements as to the occurrence and distribution of cholera.

CHAPTER XVI

DISINFECTION

DISINFECTION is the destruction of the specific virus upon which infection depends, and *disinfectant* is equivalent to *bactericide*. It is, however, often loosely applied also to *antiseptics*, that is, to substances that arrest or impede the growth of microbes without destroying their vitality, and even to *deodorants* or reagents that destroy or mask the effluvia which are the frequent by-products of bacterial growth.

It is probable that protracted exposure to air and direct sunlight (ultra-violet rays of white light) would ultimately destroy most, if not all, pathogenic microbes, although under favourable conditions the virus of tuberculosis and other transmissible diseases has been known to retain its vitality for many years. It would seem also that mere diffusion in the atmosphere may render a virus inert. Spores of pathogenic bacilli would doubtless be among the most resistant to external agencies, but mechanical portability (influenced by the form of the microbe and the size, weight, and character of the material with which it was associated), the dryness (or the reverse) of the air, the temperature, and the chemical effect of the atmospheric oxygen, are also possible factors, and it is at all events conceivable that a certain minimum "dose" of the virus is necessary for infection, so that mere dilution beyond a given point would render the virus harmless, even without destroying its vitality. According to Koch, mere drying (desiccation) kills the cholera bacillus. In considering disinfection, therefore, it is necessary to bear in mind many factors other than the direct effect of disinfection upon the "naked" and isolated bacillus.

The complete disappearance, often for long periods, of measles and other infectious diseases from a district after a widespread epidemic is in itself a sufficient proof that an enormous amount of contagium does in some way or other speedily become inert, apart from all attempts at disinfection and the exhaustion of available susceptible material.

Mechanical removal of infection from rooms or garments is often an important adjunct to disinfection proper. Walls are stripped of paper, or scraped, or rubbed with dough (Esmarch's method), or washed; floors are washed or swept; a strong current of air is sent through the room; garments are washed or brushed or beaten, and hung out in the open air. As a rule, such measures, though effectual as far as they go, are in themselves incomplete safeguards, since some portion of the virus may escape dislodgment, and there is no certainty as to the future harmlessness of the rest.

True disinfection—that is, destruction of germs—may be effected by heat or by chemical methods. It should be added that it has been abundantly proved that cold (even the great cold of liquid air, −312° F.) does not impair the vitality of organisms.

Disinfection by heat is the simplest and most thorough of all methods. With articles of small value, the safest plan is, of course, to burn them; but when this radical remedy is inapplicable, disinfection may usually be effected by exposure to moist or dry heat.

Innumerable bacteriological experiments have shown that bacteria, and even spores of some bacilli, are destroyed by exposure to steam at a temperature of 212° F. for five minutes, or to hot air at a temperature of 220–240° F. Less resistant organisms, for example micrococci or bacilli free from spores, are destroyed by hot air at 220° F. in an hour. Water at a temperature of 212° F.—that is, boiling water—is at least as efficacious as steam.

In practice the problem of disinfection is almost always complicated by the fact that the virus is not exposed freely, but protected by organic matter or enclosed in garments, pillows, or even beds; that is, in more or less bulky articles made of materials that have been selected for use as being the worst conductors of heat.[*] It is found that *steam* rapidly penetrates into the interior of such objects. The first portions condense, parting with their latent heat in so doing, and create a partial vacuum, so that successive

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[*] Wool and silk are the warmest materials used for clothing. Not only are they bad conductors of heat, but they absorb a considerable amount of moisture without becoming damp. The watery vapour of perspiration is condensed, and its latent heat rendered sensible, while the tenacity with which the moisture is held prevents re-evaporation and chill. Linen and cotton are much better conductors of heat, and absorb little water. Perspiration readily makes them damp, and they are then chilly owing to evaporation.

A brief note may be introduced here respecting the microscopic and chemical characters of these materials. *Under the microscope*, wool fibres, like hair, are straight, unbranched, and exhibit faint cross-markings and marginal indentations, due to the imbrication of the scales. Silk filaments have no such markings, and are structureless except for occasional nodes. Linen fibres have many nodes, with ragged branching filaments. Cotton fibres are flat and twisted, without nodes or branches. The chemical reactions are shown in the following table:—

Reagent.	Wool.	Silk.	Cotton.	Linen.
Potash or soda (hot strong solution) .	**Dissolves.**	**Dissolves.**	**Nil.**	**Nil.**
Sulphuric acid .	**Nil.**	**Dissolves slowly.**	**Gelatinizes.**	**Gelatinizes**
Nitric (or picric) acid	**Turns yellow.**	**Turns yellow.**	**Nil.**	**Nil.**
Zinc chloride (hot strong solution) .	**Nil.**	**Dissolves.**	—	—
Ammonium cuprate (solution of CuO in NH_3)	**Swells.**	**Dissolves.**	**Dissolves.**	**Dissolves slowly.**

supplies of steam follow continuously until a temperature of at least 212° F. is attained at the centre. *Dry hot air*, on the contrary, being dependent upon conduction, very slightly aided by convection, has no such power, and it is practically impossible to raise the temperature at the centre of a bed or similar bulky object to 212° F. by dry heat within any reasonable number of hours. Hot air moistened by steam is superior to dry hot air in penetration, but not in germicidal power, and is far inferior to steam in both respects.*

Another important consideration is the effect upon the colour and texture of fabrics exposed to heat. Articles composed in part of fusible substances, such as glue or sealing-wax, are, of course, ruined by heat in any form. Steam is inadmissible for leather and furs, since it shrivels them up and renders them worthless; hot air merely makes them temporarily dry and brittle. With these exceptions, steam is less injurious than hot air in almost all respects. New woollen goods, such as blankets and flannels, lose some of their whiteness and fleeciness by either process, but not more than in one or two ordinary washings. Silk and cotton are not injured by steam, nor by hot air if the temperature is carefully regulated. Dyes are surprisingly little affected by either steam or hot air.

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* Under ordinary atmospheric pressure of 14·7 lb. to the square inch pure water boils at 212° F.; if the pressure be doubled, at 240°; if trebled, at 273°; these being the temperatures at which the vapour tension of steam is equal to the given pressure. Further heating of water beyond the boiling-point at constant pressure (e.g. in the open air where the steam can escape freely) merely produces steam ("current steam"), the temperature of both water and steam remaining at the boiling-point corresponding to that pressure. Steam thus in contact with water, whether under pressure or not, is "wet" or "saturated," and if cooled, or if the pressure be increased, it begins at once to condense to water again. If, however, it is further heated out of contact with water, it becomes "dry" or "superheated," and behaves as a permanent gas until such time as cooling or increase of pressure brings it to the condensing point.

Steam, in condensing to water, shrinks to $\frac{1}{1200}$ of its bulk, and gives off latent heat sufficient to raise its temperature to 300° F. There is corresponding expansion and absorption of latent heat in conversion of boiling water into steam. At any given pressure the boiling-point of water containing salts in solution is slightly raised.

The essentials in a **steam disinfector** are (1) that the steam under pressure (10–20 lb. per sq. in.) shall penetrate the article to be disinfected; (2) that the temperature of the steam shall be 221–270° F.; (3) that an exposure of about 20 minutes shall be effective; (4) that all air in the disinfecting chamber shall be replaced by steam; and (5) that, after the steaming of the article, hot dry air can be passed into the chamber for drying purposes. The chief difficulty in steam apparatus is to prevent loss of heat, and condensation. This is overcome by surrounding the steam chamber with a "steam-jacket," that is, by making the wall of the apparatus double, and admitting steam into the space between the inner and outer casings. A door is provided at each end, one for the reception of infected goods, and the other for removal of the goods after disinfection. The doors are steam-tight, and are fastened by strong screw-clamps. The articles to be disinfected are placed in trays, or suspended from sliding racks. Steam disinfection may be obtained by *high pressure* (or confined) or *low pressure* (or current) steam. Both are effective, but the former is to be preferred.

Washington Lyon's apparatus is oval in section, and is usually worked with a pressure of 10–20 lb. per sq. in. in the jacket and 5–10 lb. in the chamber, so that the steam in the latter is superheated, a further precaution against condensation. The articles having been introduced, and the doors closed and secured, steam is first sent into the jacket so as to heat the contents of the chamber. Steam is next admitted into the chamber itself, and soon reaches the full pressure required. It is found that penetration is more rapid if the pressure is intermitted once or twice, which is readily effected by turning a cock. Ten to twenty minutes suffice for the penetration of even bulky objects, and at the end of that time the steam is allowed to escape from the chamber, the door is opened, and the articles are removed. Further drying may be effected if necessary by leaving the door ajar for a few minutes, and exposing the articles to heat from the jacket.

In *Goddard, Massey, and Warner's apparatus* the lower part of the jacket serves as the boiler, and the pressure in the chamber is the same as that in the jacket, usually about 20 lb., so that the steam is not superheated. After the articles are put in and the door closed, hot air is drawn through for 2 or 3 minutes, and this is repeated after the 10 or 20 minutes' exposure to steam.

The *Equifex disinfector*, upon the model of Geneste and Herscher, largely used on the Continent, has no steam jacket, but is lagged, and hot-steam pipes within the chamber serve to lessen condensation and dry the disinfected articles. The usual pressure is about 10 lb., and the steam is not superheated. There are also the *Velox* and other reliable machines.

Low-pressure steam—that is, steam under pressure only slightly, if at all, exceeding the atmospheric pressure—was found by Koch to be not inferior in germicidal power to steam at higher pressure. In *Van Overbeek de Meyer's apparatus*, in which the steam, generated at atmospheric pressure in a jacket-boiler surrounding the chamber, passed in through an opening at the top, the temperature did not exceed 212° F., but the results were practically as good as those attainable with high pressure. In *Thresh's current steam disinfector* a somewhat higher temperature is obtained without pressure, by the use of a saline solution in place of plain water in the jacket-boiler. *Reck's* is still simpler, the jacket being dispensed with.

All of these fulfil the necessary conditions—namely, rapidity of penetration, destruction of all organic life in the interior of bundles of moderate bulk without injury to fabrics, and, lastly, convenience in working. High pressure, intermitted, has perhaps some advantage in rapidity of disinfection of exceptionally bulky articles; but for ordinary purposes the simpler and less costly low-pressure apparatus is almost equally good. Esmarch has cast doubt upon the germicidal efficiency of superheated steam.

Hot-air disinfection apparatus labours under a threefold disadvantage as compared with steam. The available temperature and duration of exposure are limited by the tendency to scorch the articles exposed: the penetration of heat is so slow that it is practically impossible thoroughly to disinfect objects of moderate thickness, such as pillows; and, lastly, the germicidal effect of a given temperature is far less with hot air than with steam. The only advantage that can be claimed for hot air is that leather and bound books are not spoiled by it as they are by steam.

The best apparatus of this kind is *Ransom's*, devised many years ago. It consists of a rectangular chamber of wood and iron lined with non-conducting material. Hot air mixed with the products of combustion passes into the chamber after being heated by a number of gas jets; the temperature of the hot blast is kept constant by an automatic mercurial regulator, which controls the gas supply and can be set for any required temperature. An outlet with a chimney is provided at the top of the chamber. The best working temperature is about 255° F., this being the highest that can be used for long periods without danger of singeing cotton goods. Thermometers are placed at the inlet and outlet. It is customary to expose articles to hot air at about 255° F. for two, four, or eight hours or more, according to their bulk, but, for reasons already stated, the penetration of heat is very limited. In regard to penetration, steam accomplishes in 20 minutes what hot-air disinfection secures in 4–8 hours.

In dealing with *leather goods, furs, etc.*, formalin-vaporization may be used (175° F., with formalin, 2 parts to 100 of a 40-per-cent. solution); or they may be disinfected by formaldehyde vapour or by hot air.

It is essential that any apparatus for disinfection by heat should have doors at opposite ends, opening into entirely separate rooms provided with separate entrances. One of these rooms should be strictly reserved for infected and the other for disinfected goods, and no articles should on any account be allowed to enter the latter room except through the stove, the object being, of course, to guard against the danger of re-infection of the purified articles.

Chemical disinfection has been shown by the accurate experiments of Koch and others to be a matter of considerable difficulty, and comparatively few of the so-called disinfectants in common use prove to be really germicidal under the conditions of actual practice. A convenient but severe test is to expose to the "disinfectant," for a definite period, threads which have been soaked in a cultivation containing anthrax spores and then dried. After the "disinfection," cultivation or inoculation experiments show whether the spores survive or not, control experiments being made at the same time. Among the very few substances which killed the spores within a day (and for practical disinfection this is far more time than can often be allowed) were mercuric chloride (1 per cent.), carbolic acid and potassium permanganate (5 per cent.), and chlorine and bromine water (2 per cent.). A 4-per-cent. solution of carbolic acid took three days, and 1-per-cent. permanganate had no effect in two days. Among those which failed were 5-per-cent. solutions of chloride of lime, zinc salts, copper sulphate, ferrous sulphate, boric acid, and sulphurous acid, and 5-per-cent. carbolic oil. Several of these, however, are able to kill less resistant forms, such as *B. typhosus* and sporeless anthrax bacilli; or, serving as antiseptics, to prevent multiplication.

A substance, to be a satisfactory disinfectant, should possess five characters: (*a*) it should be directly germicidal within a reasonable time; (*b*) it should not possess chemical properties which unfit it for ordinary use; (*c*) it should be soluble in water, or capable of solution or emulsion when brought into direct contact with the material to be disinfected; (*d*) it should not produce injurious effects on the human tissues; and (*e*) it should not be too costly when used in appropriate strength. The substances which fulfil all these requirements are not numerous. Many valueless experiments have been made respecting such chemical bodies, because the conditions necessary to valid and comparable results have been ignored. These conditions are chiefly three, namely, using disinfectants which give regular and consistent results, using standardized bacterial cultures as to age and source, and working with the same organism. Out of the confusion of contradictory findings it is possible, however, to name a number of reliable disinfectants. The liquid reagents most in use are mercuric chloride (1-500 for excreta and 1-1,000 for hands), mercuric iodide (1-1,000 for stools and linen, and 1-2,000 for hands), potassium permanganate (5 per cent.), formalin (40 per cent. solution of formic aldehyde mixed in equal volume for stools), carbolic acid (5 per cent.), zinc chloride (1-10), chloride of lime (1 to 2 per cent. for hand-washing, etc., 4 per cent—i.e. 6 oz. to 1 gallon—for solid and liquid excreta), creosol, cyllin, lysol, creolin, and many compounds of the aromatic series (e.g. izal and Jeyes' fluid, which contain the higher phenols, and form emulsions with water).

A most important consideration in regard to the more potent of these disinfecting solutions is their "working strength." If, for example, it is proposed to disinfect a putrescent liquid by means of permanganate of potash, it is absolutely useless to add a little of a 5-per-cent. solution of the salt: We must add either the solid permanganate or a highly concentrated solution, until the permanganate is present as such to the extent of 5 per cent. of the whole weight of liquid, this 5 per cent. being, of course, in addition to the amount required to oxidize the organic matter. These essential conditions are rarely if ever observed in practice, and "disinfection" by permanganate consists usually of deodorization with partial oxidation of organic matter. A similar consideration applies to mercuric chloride, which, if added to liquids containing organic matter, forms a precipitate that carries down part of the mercury in an inert form, and, if sulphuretted hydrogen is present, the equally inert sulphide of mercury is thrown down. So, too, with carbolic acid, which must form not less than 5 per cent. of the whole weight of liquid—not merely of the stock solution—if it is to destroy anthrax spores.

Mercuric chloride is one of the chief reagents that can be conveniently employed in solution under such conditions as to destroy the most resistant microbes.

One part of mercuric chloride in 1,000 of water destroys anthrax spores, according to Koch, but other observers have found this strength inadequate. The great drawback to this reagent is its extremely poisonous nature, but it may be kept in fluted poison-bottles properly labelled, and the solution may be artificially coloured with indigo, and "odorized" with thymol, as further safeguards. The following proportions are suggested in a memorandum of the **L.G.B.** (1905): ½ oz. mercuric chloride, 1 oz. hydrochloric acid, and 5 grains of commercial aniline blue, in 3 gallons of water. This ought not to cost more than one penny per gallon and should not be further diluted. Non-metallic vessels (wooden or earthenware) should be used, and articles soaked in the mercurial solution should be steeped in water for some hours before washing. Whether the contagia of human diseases are amenable to less potent reagents is still an open question, but for the present it is not safe to assume this.

Many fluid disinfectants are now applied direct to infected surfaces by means of a *sprayer* (Equifex, Mackenzie, etc.), such as chloride of lime (1 lb. to 10 gallons of water), carbolic acid (5 per cent.), formalin (40 per cent. solution, 5 oz. to the gallon for 500 ft. of surface).

Fumigation.—For the disinfection of rooms and other closed spaces the principal reagents in use are sulphurous acid, chlorine, bromine, nitrous acid, and formic aldehyde. *Sulphurous acid* is usually generated by setting fire to fragments of roll sulphur in an iron vessel, with the addition of a little spirit to facilitate lighting. Sulphur candles are convenient substitutes, or bisulphide of carbon may be burnt in a lamp. The prescribed proportions are 2 to 3 lb. of sulphur to every 1,000 cub. ft. of air-space.

Chlorine is most conveniently produced by adding crude hydrochloric acid to chloride of lime. The strength of the latter varies, but as a rule 1½ to 2 pints of the acid should be allowed for each pound of chloride of lime. No heat is required; indeed the reaction is so rapid that it is necessary to secure time for the operator to escape, by letting the acid drip through a small hole upon a little cup which, when full, overflows into the dish containing the lime. The quantities required, according to German experiments, are very large—about 15 lb. of chloride of lime and 22 lb. of hydrochloric acid * for every 1,000 cub. ft. These quantities, being somewhat prohibitive, are commonly reduced to one-tenth or less in practice. The reagents should be divided into a convenient number of portions and placed in several parts of the room in positions as near the ceiling as may be practicable.

Nitrous fumes are generated by adding copper filings or other reducing agents to nitric acid.

Formic aldehyde vapour can be obtained by various devices in the way of lamps (paraform lamp burning 60 tabloids per 1,000 cub. ft., exposure 5–10 hours); more effectively by Trillat's autoclave, a somewhat costly apparatus, in which its 40 per cent. aqueous solution, known as formalin, is treated at high pressure in presence of calcium chloride, the gas being passed through the keyhole by means of a tube; or by Lingner's apparatus, in which glyco-formal (formalin 30 per cent. and glycerin 10 per cent.) is vaporized and ejected as a fine spray. If the formalin is simply heated, much of the aldehyde changes into a solid polymeride *paraform*. The amount of formalin required for each 1,000 cub. ft. of air-space in a room is about a pint (20 oz.). The vapour, in the proportion of 1 per cent. in air, or solution of 0·5 per cent.

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* Strong sulphuric acid may be substituted for crude hydrochloric acid. About a third of the quantity would suffice.

strength, is found to destroy most organisms. For purposes of fumigation, formic aldehyde has advantages over sulphurous acid and chlorine, in its lower density, which gives it greater diffusibility and some power of penètration, and in its more rapid action (3–5 hours). It acts best if the air is dry, and it is harmless to most colours and most surfaces except iron. The vapour is irritating, but readily cleared away by ventilation.

Klein, Houston, and Gordon, in 1902, found that formic aldehyde gas (30 tabloids of 0·034 oz. each to 1,000 cub. ft. space) killed the cholera and typhoid bacilli, and the diphtheria bacillus, as well as *Staphylococcus pyogenes aureus*, in 5 hours, and devitalized tubercular sputum unprotected and freely exposed on linen and paper. The same may be said of sulphurous acid gas (3 lb. to 1,000 cub. ft.) in 24 hours, except that the sputum remained unaffected. Anthrax spores were not killed uniformly under any of these conditions.

Sealing of room.—In any case the room must be rendered as nearly air-tight as possible before fumigation. Paper should be pasted over the fireplaces and ventilators, and around the window-sashes and doors, leaving, of course, one door to be pasted up on the outside after the operator quits the room. It is desirable to render the air of the room moist by means of steam or water before fumigating by sulphurous acid or chlorine, to an extent sufficient to moisten the walls and other surfaces. In ordinary rooms it appears that the unavoidable leakage is considerable, so that the theoretical proportion of the gas is only present for a very short time, if at all. The slightest protection shields even sensitive microbes from the action of the fumigant; very few are killed which lie in crevices, or in the pocket of a coat, or are wrapped in filter-paper.

It would seem that, if precautions are taken to reduce the leakage to a minimum, fumigation by sulphurous acid, chlorine, or formic aldehyde may be able to destroy most, if not all, of those microbes that are not very resistant, and that happen to be freely exposed upon the surface.

Fumigation is to be regarded as—at most—a disinfection of air and of surface. Even this is an important step in the direction of safety, for the surface is precisely that portion of an infected article which is most readily and most largely charged with infective matter. As a preliminary process it affords some degree of security to those engaged in carrying out later and more thorough measures of disinfection. It can be supplemented, as regards surfaces, by washing with soap and water, or spraying with a disinfectant solution; wall-papers can be stripped off, or limewash renewed.

Disinfection of the air of a room is practically ensured by the free ventilation which in any case must be subsequently effected; but if infected surfaces or articles are allowed to remain undealt with, the air may at any time again become charged with infective matter accidentally dislodged from its resting-place; therefore, in addition to fumigation it is necessary thoroughly to wash with disinfectant (e.g. 1-1,000 corrosive sublimate).

Besides the germicidal power of the reagent there are three other conditions essential to disinfection—namely, sufficient strength or intensity, maintained for a sufficient time, with sufficient contact or exposure.

In few departments of hygiene have absurd generalizations been so prevalent as in reference to disinfection. "Disinfectants," or substances labelled as such, are still widely employed under conditions which a moment's reflection would show to be utterly incompatible with any real efficacy. Passing over such trivialities as "fumigation" by burning brown paper or green sticks, we have the wholesale employment of deodorants and antiseptics under the name of disinfection, unsupported by any scientific evidence of their utility. The few true disinfectants in general use are commonly employed under such conditions as to quantity, concentration, and duration of exposure that little benefit can result from them. It is often asserted that the danger of infection by diseased meat is exaggerated, because the process of cooking must destroy any microbes that may be present. Even as regards microbes, the temperature in the interior of joints obviously may fall far short of that required for disinfection, and toxins are in all probability uninjured by ordinary cooking. The gastric juice also is credited with a disinfecting power much greater than the evidence warrants.

Attempts are often made to "disinfect" sewers and drains by flushing them with solutions of chloride of lime, carbolic acid, or ferrous sulphate. A little consideration will render it clear that any real disinfection of this kind is wholly impracticable, even if true disinfectants such as strong solutions of mercuric chloride are used. The reagent is quickly diluted by the contents of the drain, and rapidly passes away without coming even momentarily into effectual contact with the whole of the material and surfaces it is supposed to disinfect. If the drain or sewer is properly constructed, thorough flushing by water will be more effectual than the use of disinfectants.

Standardization of disinfectants.—Koch and other bacteriologists made early attempts to standardize the disinfectant power of the chemical substances with which they experimented. Complete and exact standardization is, of course, impossible owing to the variability of the protoplasm and resistant powers of different micro-organisms and even different strains of the same species. Two tests have been recognized for standardizing disinfectants, the Rideal-Walker and the Martin-Chick. (*a*) The Rideal-Walker test is as follows: To 5 c.c. of a particular dilution of the given disinfectant in sterilized water are added 5 drops of a 24-hours' blood-heat-incubated culture of the organism in broth. Mix thoroughly, and then subculture every 2½ minutes up to 15 minutes, and incubate for 48 hours at 37° C. The germicidal potency of the given disinfectant is expressed in multiples of a solution of pure phenol performing the same work in the same time, with a 24-hours' culture in broth of the typhoid bacillus, and this constitutes the "carbolic-acid coefficient." (*b*) In the Martin-Chick test an emulsion is made containing 3 per cent. of human fæces, dried at 216° F. and subsequently sterilized, to which the test organism is added. To this is added the disinfectant to be standardized, allowing an interval of 15 minutes, and subculturing. The coefficients obtained are much less than in test (*a*).

Antiseptics are reagents which prevent, arrest, or impede the growth and multiplication of microbes, without necessarily destroying them. All true chemical disinfectants are still antiseptic when diluted, provided that the dilution is not carried too far (mercuric chloride has some trace of antiseptic power even at the enormous dilution of 1 in 300,000). Among other important antiseptics are boric acid, borax, sulphurous acid; essential oils, including those of mustard, thyme, turpentine, peppermint, cloves, and eucalyptus; quinine and other alkaloids; and flavine.

Antiseptics are employed mainly to prevent or arrest decomposition of organic substances. Apart from surgical purposes, they are used for the preservation of food, to prevent or restrain decomposition in organic refuse, as a precaution against rotting of timber, and in many other ways.

Deodorants serve to remove or mask effluvia. Among aerial deodorants, nitrous acid is one of the most powerful. Chlorine and the fumes given off by moist chloride of lime are also potent, and act by oxidation of organic matter; they decompose sulphuretted hydrogen, which is an important constituent of the gases of putrefaction.

CHAPTER XVII

MEDICAL OFFICERS OF HEALTH AND SANITARY INSPECTORS

Medical Officers of Health.—Every Sanitary Authority is required (Public Health Act, 1875, secs. 189, 190) to appoint one or more Medical Officers of Health, and also an Inspector of Nuisances. Two or more **S.A.s** may appoint the same **M.O.H.** (under s. 191); and, apart from this, the **L.G.B.** is empowered (s. 286) compulsorily to unite districts for the purpose of appointing a **M.O.H.** County Councils are required, by s. 68 (1) of the Housing and Town Planning Act, 1909, to appoint (county) Medical Officers of Health, who are forbidden to hold other appointments or engage in private practice without the written consent of the **L.G.B.** The **M.O.H.** may, however, hold the post of School Medical Officer for his area. If any part of the salary of the **M.O.H.** of a local Authority is repaid by the County Council, the **L.G.B.** has the same powers in regard to qualification, appointment, duties, salary, and tenure of office as it has in the case of a Poor Law medical officer (Public Health Act, s. 191).

In December, 1910, the **L.G.B.** issued a Memorandum on the whole subject of the appointment of Medical Officers of Health, in which they emphasized the advantages of whole-time appointments. In order to secure such appointments it is frequently desirable for small districts to combine, an arrangement approved by the Board. It is, in the Board's opinion, also desirable, for economy and efficiency, that certain posts should be held conjointly by the same officer, viz. **M.O.H.**, **S.M.O.** and assistant **S.M.O.**, superintendent of the local isolation hospital, certifying factory surgeon, and, in the same district, public surgeon, public vaccinator, and poor-law medical officer. The **M.O.H.** may also, where qualified, undertake analytical and bacteriological work. It forms, however, no part of the ordinary duties of the **M.O.H.** to make full analysis of milk, water, sewage effluents, etc.

Qualifications.—The Orders issued by the **L.G.B.** require that the **M.O.H.** shall be registered under the Medical Act of 1858, and be qualified by law to practise both medicine and surgery in England and Wales. The powers of the Board in this respect are practically superseded by the Local Government Act, 1888, s. 18 of which requires that (except when the **L.G.B.**, for reasons brought to their notice, may see fit in particular cases to allow otherwise) every **M.O.H.** appointed after the passing of the Act shall be legally qualified for the practice of medicine, surgery, and midwifery; and further, by the same section, he must, if appointed after the 1st of January, 1892, to a district having at the last census 50,000 inhabitants or more, appear in the Medical Register as the holder of a diploma in Sanitary Science, Public Health, or State Medicine under s. 21 of the Medical Act, 1886; or have been, during some three consecutive years prior to 1892, a medical officer of a district with a population (according to the last census) of not less than 20,000; or have been for not less than three years a medical officer or inspector of the **L.G.B.**

Tenure of office.—Every medical officer appointed to hold office without limit of time shall continue to hold office until he dies, resigns, or is removed by the **L.G.B.**, or by the Council with the assent of the

L.G.B., or is proved to be insane. Subject to the provisions of the Order, every officer appointed for a specified term shall, on the expiration of that term, unless the Council three months prior to the expiration of the term by resolution otherwise determine, continue to hold office from year to year until he dies, resigns, or is removed by the **L.G.B.**, or by the Council with the assent of the **L.G.B.**, or is proved to be insane, and no further reappointment of the officer by the Council, and no further approval of his appointment by the **L.G.B.**, shall be required unless the terms of the appointment are altered. Provided always that the Council, after the expiration of the specified term, may terminate the appointment by giving to the officer three months' written notice of their intention to do so, and such notice shall take effect at the same period of the year as that at which the original term expired and not otherwise. A copy of such notice shall be sent to the **L.G.B.** at the same time as the notice is sent to the officer. The Council may at any time, by resolution and with the consent of the **L.G.B.**, appoint an officer who holds an appointment for a specified term to hold office without limit of time.

The Council may, at their discretion, suspend any officer from the discharge of his duties, and shall, in case of every such suspension, forthwith report the same, together with the cause thereof, to the **L.G.B.**, who may remove the suspension of the officer by the Council, when he shall forthwith resume his duties. Where any change in the extent of the district of any officer, or in his duties or salary, is deemed necessary by the Council or the **L.G.B.**, and he declines to acquiesce therein, the Council may, with the consent of the **L.G.B.**, but not otherwise, and after six months' notice in writing, signed by their Clerk, given to the officer, determine his office,

Salary.—The salary has to be approved by the **L.G.B.**, and with the consent of this Board the Council may pay a reasonable remuneration on account of extraordinary services, or other unforeseen or special circumstances connected with his duties or the necessities of the district for which he is appointed. In all cases of whole-time appointments it is important that the salary should be adequate to attract men with good qualifications and wide experience, and to retain their services.

Duties.—The duties of Medical Officers of Health as prescribed by the **L.G.B.** are the same whether a contribution is made to the salary or not, except that in the latter case the officer is obliged to report his appointment within seven days to the **L.G.B.**

The following duties are prescribed by the Board's Order of 1910 (Art. 19) for every **M.O.H.** appointed or reappointed after that date:—

1. He shall inform himself as far as practicable respecting all influences affecting or threatening to affect injuriously the public health within the district.

2. He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

3. He shall by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

4. He shall be prepared to advise the Council on all matters affecting the health of the district, and on all sanitary points involved in the action of the Council; and in cases requiring it, he shall certify, for the guidance of the Council or of the justices, as to any matter in respect of which the certificate of a **M.O.H.** or a medical practitioner is required as the basis or in aid of sanitary action.

5. On receiving information of the outbreak of any infectious or epidemic disease of a dangerous character within the district, he shall visit without delay the spot where the outbreak has occurred, and inquire into the causes and circumstances of such outbreak, and, in case he is not satisfied

that all due precautions are being taken, he shall advise the persons competent to act as to the measures which appear to him to be required to prevent the extension of the disease, and shall take such measures for the prevention of disease as he is legally authorized to take under any statute in force in the district or by any resolution of the Council.

6. Subject to the instructions of the Council, he shall direct or superintend the work of the Inspector of Nuisances in the way and to the extent that the Council shall approve, and on receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable take such steps as he is legally authorized to take under any statute in force in the district, or by any resolution of the Council, as the circumstances of the case may justify and require.

7. In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the Council, he shall himself inspect and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, and any other article to which the provisions of the Public Health Acts in this behalf apply, exposed for sale, or deposited for the purpose of sale or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be dealt with by a justice according to the provisions of the statutes applicable to the case. He shall also take such action as it may be necessary for him to take by virtue of the provisions of the Public Health (Regulations as to Food) Act, 1907, and any regulations made thereunder.

8. He shall perform all the duties imposed upon him by any bye-laws and regulations of the Council, duly confirmed where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorized to frame bye-laws and regulations.

9. He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

10. He shall attend at the office of the Council, or at some other appointed place, at such times as they may direct.

11. He shall from time to time report in writing to the Council his proceedings, and the measures which may require to be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been able to ascertain the same.

12. He shall keep a book or books, to be provided by the Council, in which he shall make an entry of his visits, and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon and of any action taken on previous reports; and shall produce such book or books, whenever required, to the Council.

13. On Monday, the 9th of January, 1911, and on every Monday thereafter, he shall forward to the **L.G.B.** by post, at such an hour as in the ordinary course of post will ensure its delivery on the following Tuesday morning, a return, in such form as the **L.G.B.** may from time to time require, as to the number of cases of infectious disease notified to him during the week ended on the preceding Saturday night. He shall also forward at the same time a duplicate of the return to the Medical Officer or Officers of Health of the county or counties in which the district is situated.

14. He shall as soon as practicable after the 31st of December in each year make an annual report to the Council, up to the end of December, on the sanitary circumstances, the sanitary administration, and the vital statistics of the district.

In addition to any other matters upon which he may consider it desirable to report, his annual report shall contain the information indicated in the following paragraphs; together with such further information as the **L.G.B.** may from time to time require:—

(*a*) An account of any influences threatening the health of the district, the prevalence of infectious or epidemic diseases therein, and the measures taken for their prevention.

(*b*) An account of all general and special inquiries made during the year.

(*c*) An account of the work performed by the Inspector of Nuisances during the year, including the statement supplied in pursuance of Article xx. (16) of this Order.

(*d*) A statement as to the conditions affecting the wholesomeness of the milk produced or sold in the district.

(*e*) A statement as to the conditions affecting the wholesomeness of foods for human consumption, other than milk, produced or sold in the district.

(*f*) A statement as to the sufficiency and quality of the water supply of the district and of its several parts, and, in areas where the supply is from waterworks, information as to whether the supply is constant or intermittent.

(*g*) A statement as to the pollution of rivers or streams in the district.

(*h*) A statement as to the character and sufficiency of the arrangements for the drainage, sewerage, and sewer disposal in all parts of the district.

(*i*) A statement as to the privy, water-closet, and other closet accommodation in the district, including information as to the approximate number of each type of privy and closet.

(*j*) A statement as to the character and efficiency of the arrangements for the removal of house-refuse, and the cleansing of earth-closets, privies, ashpits, and cesspools in the district.

(*k*) A statement with regard to the housing accommodation of the district as required by Article v. of the Housing (Inspector of District) Regulations, 1910, and an account of any other action taken by the Council under the Housing, Town Planning, etc., Act, 1909, bearing on the public health.

(*l*) A statement as to the vital statistics of the district, including a tabular statement, in such form as the **L.G.B.** may from time to time direct, of the sickness and mortality within the district.

(*m*) Where the **M.O.H.** is appointed by the Council of a county borough, or by a Council having delegated powers under the Midwives Act, 1902, a statement as to the administration of that Act in the district:

Provided that, if the **M.O.H.** shall resign or be removed before the 31st of December in any year, he shall, as soon as practicable after going out of office, make to the Council the like report for so much of the year as shall have expired when he ceased to hold office.

15. He shall forthwith report to the **L.G.B.** any case of plague, cholera, or smallpox, or of any serious outbreak of epidemic disease in the district, which may be notified to him, or which may otherwise come or be brought to his knowledge.

16. He shall transmit to the **L.G.B.** three copies of each annual report and one copy of any special report. At the same time he shall transmit a copy of the report or give the like information to the County Council or County Councils of the county or counties within which the district is situated. Where the **M.O.H.** is appointed by the Council of a county borough, or by a Council having delegated powers under the Midwives Act, 1902, he shall also transmit to the Privy Council and to the Central Midwives Board either a copy of his annual

report or of that part of it which contains the statement relating to the administration of the Midwives Act, 1902.

17. In matters not specifically provided for in this Order, he shall observe and execute any instructions issued by the L.G.B., and the lawful orders and directions of the Council applicable to his office.

18. Whenever the L.G.B. shall make regulations, and shall declare the regulations so made to be in force within any area comprising the whole or any part of the district, he shall observe such regulations, so far as the same relate to or concern his office.

The duties of the **M.O.H.** to a Port **S.A.** are defined by the **L.G.B.** in terms which are closely parallel to those given above, omitting the references to regulated trades and inspection of food, and other matters clearly concerned with ordinary sanitary districts, and substituting "ships" for "houses," and "shipping within the district" for "district."

"He shall inform himself as far as practicable respecting all conditions affecting or threatening to affect injuriously the health of crews and other persons on ship-board within the district. . . . . He shall inquire into, and ascertain by such means as are at his disposal, the causes, origin, and distribution of diseases in the ships and other vessels within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation. . . . . . He shall, by inspection of the shipping in the district, keep himself informed of the conditions injurious to health existing therein. . . . . On receiving information of the arrival within the district of any ship having any infectious or epidemic disease of a dangerous character on board, or of the outbreak of any such disease on board any ship within the district, he shall visit the vessel without delay, and inquire into the causes and circumstances of such outbreak, and advise the persons competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and so far as he may be lawfully authorized to assist in the execution of the same. . . . . On receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a ship, he shall, as early as practicable, take such steps authorized by the Public Health Act, 1875, on that behalf, as the circumstances of the case may justify and require. . . . . When any vessel within his district has had dangerous infectious disease on board, he shall give notice thereof to the **M.O.H.** of any port within the United Kingdom whither such vessel is about to sail."

Duties of County Medical Officers of Health.—Section 68 of the Housing, Town Planning, etc., Act, 1909 (subsection 1), requires every County Council to appoint a **M.O.H.**, and in July, 1910, the **L.G.B.** issued a General Order setting out the duties of these officers.

The Board have not included any provision requiring the **M.O.H.** of the county to compile periodical lists of infectious disease, as these are now obtained weekly by the **L.G.B.** from the district **M.O.H.**

The Board regarded any provision as to the co-ordination of the work of the **S.M.O.** under the Education (Administrative Provisions) Act, 1907, with the work of the county **M.O.H.**, as not immediately within the scope of the Order. Both they and the Board of Education consider that this co-ordination should be as close as possible, and that it can best be secured by the appointment of the same officer as county **M.O.H.** and county **S.M.O.** The duty of serving as **S.M.O.** is clearly within the scope of those "other duties" which, under the Act, may be assigned by the County Council to its **M.C.H.** Where the work of the two offices is more than can be discharged by one officer, the case should be met by the appointment of assistants, rather than by the appointment of separate and independent officers. In some instances it may be desirable that such additional assistance as is required in regard to school hygiene should be obtained by the appointment, as an assistant **S.M.O.**, of the **M.O.H.** of a district or combination of districts in the county. The adoption of this course may enable the Councils of the districts concerned to obtain the advantage of the services of an officer who does not engage in private practice.

Subsection 7 of s. 68 of the Act provides that a **M.O.H.** appointed after the passing of the Act shall not engage in private practice, and shall not hold any other public appointment without the express written consent of the **L.G.B.**, and subsection 3 takes away the power of County Councils and District Councils under s. 17 of the Local Government Act, 1888, to make arrangements to employ the same **M.O.H.** As indicated above, the Board are prepared to consent to the **M.O.H.** holding also the office of **S.M.O.** in the county, but they think it is generally undesirable that any other offices should be held by the county **M.O.H.** In regard to the remuneration of the **M.O.H.**, the Board's experience shows that it is desirable that in addition to his salary the officer should be repaid his actual travelling expenses, and that he should be provided with adequate clerical assistance. The Board point out that to secure the best interests of the county in the department of public health co-operation between the county **M.O.H.** and the district **M.O.H.** is essential.

The Order prescribes the following duties as the duties of every Medical Officer of Health of a county other than the administrative county of London :—

1. The **M.O.H.** of the county shall inform himself as far as practicable respecting all influences affecting or threatening to affect injuriously the public health in the county. For this purpose he shall visit the several county districts in the county as occasion may require, giving to the **M.O.H.** of each county district prior notice of his visit, so far as this may be practicable.

2. The **M.O.H.** of the county shall from time to time inquire into and report upon the hospital accommodation available for the isolation of cases occurring in the county—

(*a*) of smallpox, and (*b*) of other infectious diseases, and upon any need for the provision of further hospital accommodation.

3. The **M.O.H.** of the county shall communicate to the **M.O.H.** of a county district within the county any information which he may possess as to any danger to health threatening that district.

4. The **M.O.H.** of the county shall consult with the **M.O.H.** of county districts within the county whenever the circumstances may render this desirable.

5. If the annual or special reports of the **M.O.H.** of a county district in the county shall not contain adequate information in regard to (*a*) the vital statistics of the district, (*b*) the sanitary circumstances and administration of the district, and (*c*) the action taken in the district for putting in force the provisions of the Housing of the Working Classes Acts, 1890 to 1909, the **M.O.H.** of the county shall obtain from the **M.O.H.** of the county district such further information on those matters as the circumstances may demand.

6. The **M.O.H.** of the county shall, when directed by the **L.G.B.**, or by the County Council, or as occasion may require, make a special report to the County Council on any matter appertaining to his duties under this Order.

7. The **M.O.H.** of the county shall, as soon as practicable after the 31st day of December in each year, make an annual report to the County Council up to the end of December on the sanitary circumstances, the sanitary administration, and the vital statistics of the county. In addition to any other matters upon which the **M.O.H.** may consider it desirable to report, his annual report shall contain the following sections: (*a*) A digest of all annual and special reports made by the **M.O.H.** of all county districts within the county; (*b*) a section as to the isolation-hospital accommodation available for each county district and as to the steps which should be taken to remedy any deficiencies which may exist; (*c*) a section on the administration of the Housing of the Working Classes Acts, 1890 to 1909, within the county; (*d*) a section on the water supply of the several county districts within the county; (*e*) a section on the pollution of streams within the county and as to the steps for the prevention of pollution taken (i.) by the Local Authorities and (ii.) by the County Council; (*f*) a section on the administration within the county of the Midwives Act, 1902; and (*g*) a section on the administration of the Sale of Food and Drugs Acts, 1875 to 1907, within that part of the county in which the County Council have jurisdiction for the purposes of those Acts.

8. The **M.O.H.** of the county shall send to the **L.G.B.**

two copies of his annual report and two copies of any special report; he shall also send one copy of his annual report to the Council of every county district in the county, and shall send three copies of any special report to the Council of every such county district affected by the special report.

Annual reports.—Under the Local Government Act, 1888, s. 24 (2) (c), one-half of the salary of a **M.O.H.** is forfeited, and the **S.A.** lose the benefit of repayment of a moiety of the salary by the County Council, if the **M.O.H.** does not furnish an annual report as required by the Regulations. The following instructions were issued by the **L.G.B.** in November, 1910:—

Every **M.O.H.** appointed under Order of the **L.G.B.** is required to make an annual report with regard to each sanitary district, or division of a district, which is under his superintendence. This report is to be for the year ending the 31st of December, or, if the officer at that date has not been in office for a whole year, then for so much of the year as has elapsed since his appointment. The report is to be made to the Council by whom he is appointed, and the **M.O.H.** himself should send a copy of it to the **L.G.B.** and to the County Council or County Councils of the county or counties within which his district may be situated.[*] It should be made as soon as practicable after the expiration of the year to which it relates. The **M.O.H.** ought not to have any difficulty in doing this within two months; but if, from any special circumstances the report cannot be completed within this period, it should be understood that the delay must not be indefinite, and that the report should be in the hands of his Council, and of the Board, within, at most, three months from the end of

[*] Where the district for which a **M.O.H.** acted at the beginning of the year has, in consequence of any Order made by a County Council or Joint Committee under the Local Government Acts, 1888 and 1894, been placed under the jurisdiction of two or more Councils, the **M.O.H.** should send to each Council, either a report on the whole area for which he has acted during the previous year, or a report relating to so much of that area as on the 31st December of that year was under the jurisdiction of each Council. If one report only be made, the **M.O.H.** should make such distinctions as will enable each Council to ascertain the facts specially relating to its own district.

In cases where the Local Authority having jurisdiction over an area at the beginning of the year has ceased to exist, the **M.O.H.** should report thereon to the Council or Councils exercising authority over such area at the time that he makes his annual report.

the year.* Any special circumstances preventing the delivery of the Board's copy within three months from the end of the year should at once be reported to the Board. The Board's copy of the report should be forwarded to them when the original is sent to the Council, unless the report is about to be printed by order of the Council. In such cases the Board need only be supplied with three printed copies. It is very desirable that the annual report should be printed, for the sake of facility of reference and in order that a supply of copies may be available for distribution among the town or district councillors and other persons interested.

Article 18 (s. 14) of the Board's Order of March, 1891, specifies the information to be contained in the annual report.

The report should be chiefly concerned with the conditions affecting health in the district and with the means for improving those conditions. It should contain an account, brought up to the end of the year under review, of the sanitary circumstances of the district, and of any improvement or deterioration in these circumstances which may have occurred during the year. Care should be taken to report fully and explicitly on the influences affecting or threatening to affect injuriously the public health in the district, and on the action which has been taken, or which may still be needed, with a view to combat those influences. It is of especial importance that the **M.O.H.** should record what action has been taken to remedy unhealthy conditions which have been reported by him in previous annual reports, or in special reports presented during the year under review, and that attention should be called afresh, year by year, to such as remain unremedied.

The following deserve to be especially borne in mind as subjects concerning which the Board desire to obtain, through annual reports of the **M.O.H.**, not only definite general information, but record also of particular changes of condition that may have occurred incidentally or by action of the Local Authority:—

Physical features and general character of the district and general conditions of its population.

The chief occupations of the inhabitants, and the influence of any particular occupation on public health.

House accommodation, especially for the working classes: its adequacy and fitness for habitation. Sufficiency of open space about houses, and cleanliness of surroundings. Supervision over erection of new houses. Action under Parts I., II. and III. respectively of the Housing of the Working Classes Act, taken or needed.

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* Medical Officers of Health sometimes delay issuing their annual reports in order to incorporate in them some of the statistics of the Registrar-General for the same year. The rates required for this purpose are given in the Quarterly Return of Births and Deaths of the Registrar-General for the last quarter of the year in question, which is published about six weeks after the end of the year.

Water supply of the district or of its several parts: its source (from public service or otherwise), nature (river water, well water, upland water, etc.), sufficiency, wholesomeness, and freedom (by special treatment or otherwise) from risks of pollution. In the case of water liable to have plumbo-solvent action, any facts, either clinical or chemical, whether negative or positive, as to contamination of the water by lead should be stated, and whether administrative action has been taken during the year in respect of such contamination.

Milk supply: character and wholesomeness of milk produced within the district or imported; condition of dairies, cowsheds, and milkshops; administration in regard to milk. Tuberculous milk.

Other foods: unsound food and food inspection; sanitary condition of premises where foods are prepared, stored, or exposed for sale. Meat inspection, disease in meat, and condition of slaughterhouses. Action under Sale of Food and Drugs Acts, taken or needed. Action under s. 117 of the Public Health Act, 1875. Number of carcasses and parts of carcasses condemned for tuberculosis. Information on this point should be given even when entirely negative.

Sewerage and drainage: its sufficiency in all parts of the district. Condition of sewers and house drains. Method or methods of disposal of sewage. Localities where improvements are needed.

Pollution of rivers and streams in the district: the sources and nature of such pollution, and any action taken to check it.

Excrement disposal: system in vogue; defects, if any.

Removal and disposal of house refuse—whether by public scavenger or occupiers: frequency and method.

Nuisances: proceedings for their abatement—any remaining unabated.

Bye-laws as to houses let in lodgings, offensive trades, etc. Details as to number of premises coming under each set of bye-laws, and action taken. Any need of amendment or further bye-laws.

Schools, especially public elementary schools: sanitary condition of, including water supply; action taken in relation to the health of the scholars and for preventing the spread of infectious disease. Arrangements for medical inspection of school children.

Methods of dealing with infectious diseases: notification; isolation hospital accommodation, its sufficiency and efficiency; disinfection.

Methods of control of tuberculosis: whether any system of notification of cases of pulmonary tuberculosis, compulsory or voluntary, is in operation. Number of cases notified; what action is taken in respect of known cases and of deaths. Amount of hospital accommodation for cases of pulmonary tuberculosis in infirmaries and elsewhere, for advanced and for earlier cases of the disease.

With regard to the preceding points it should be remembered that these reports are for the information of the Board and of the County Council as well as of the Council of the district, and that a statement of the local circumstances and a history of local sanitary questions which may seem superfluous for the latter may often be needed by the former bodies.

It is expected that each of the preceding points will be mentioned in the annual report, and the extent of action or the absence of action on each of them definitely stated.

The report should deal with the extent, distribution, and causes of disease, especially of epidemic and notifiable diseases, and of tuberculosis within the district; and should give an account of any noteworthy outbreaks of disease which may have engaged the attention of the **M.O.H.** during the year under review, stating the result of his investigations into their origin and propagation, and the steps taken by him, or on his advice, with a view to check their spread. Attention should be called to cases in which disease is attributed to the consumption of particular articles of food, including shell-fish.

In dealing with the incidence of disease, use should be made of the tabular statements supplied by the Board.

This section of the report should treat of each disease in turn; and it will be convenient in the same connexion to describe the administrative action taken. Thus the administration of the Midwives Act may with advantage be considered in relation to puerperal fever, and of the Notification of Births Act, 1907, in relation to infant mortality.

If the last-named Act has been adopted, the **M.O.H.** should report fully in his annual report on the measures taken by assistance of the Act in repression of infant mortality, and on the observed effect of such measures. It should be stated whether health visitors are employed; and, if so, the work done by them in the course of the year should be set out.

Table IV. issued by the Board affords opportunity for record in detail of facts as to infant mortality. It is well known that in many parts of this country the infantile death-rate remains unduly high; that it differs widely in districts the circumstances of which are not definitely dissimilar; and that within the limits of a given sanitary area this death-rate may exhibit striking diversities. Not a few **M.O.H.**, in their annual reports—more particularly in reports for recent years—have dealt in detail with this subject, thus making important contributions to the better understanding of conditions which conduce to infant mortality. Nevertheless, statistics available in this connexion do not afford, except in a broad and general way, satisfactory bases for comparison of district with district, nor, indeed, always for useful contrast of different sections of the same district.

Table IV. permits record in regard of each sanitary district as a whole (as also in respect to each of particular subdivisions of his district which the **M.O.H.** may select for comparison) of certain facts as to infant mortality in each of the several weeks of the first month of life and in subsequent months; facts which, when accumulated for a series of years, should prove of definite value in instituting comparisons such as have been referred to. In the text of his annual report, the **M.O.H.** will, no doubt, comment on the facts that he has recorded in his table or tables, offering, at the same time, observations on the conditions which, in his view, have mainly contributed to any special infant mortalities witnessed, and giving account of any measures adopted to ameliorate those conditions regarded by him as especially hostile to infant life. In so far as modification of procedure for the purpose, or of law in facilitating such modification, is in his opinion necessary, the **M.O.H.** is invited to state his views.

It is not proposed that report on the above lines be limited to districts exhibiting unduly high infantile death-rates. Data are desirable respecting districts low in the scale of infant mortality, with comment by the **M.O.H.** on the facts that he is recording, and indication of the conditions which, in his view, have principally conduced in his district to comparatively insignificant infantile death-rate.

In reference to schools, the Memorandum on Medical Inspection of Children in Elementary Schools (Circular 576) issued by the Board of Education in November, 1907, dealing with the new duties thrown upon Local Education Authorities in this respect by Section 13 of the Education (Administrative

Provisions) Act, 1907, and also Circulars 582 and 596 issued by the Board of Education in February and August, 1908, should be carefully studied. The above Act does not confer powers in supersession of those heretofore exercised generally in a public health sense by Sanitary Authorities under previous enactments; rather it is supplementary to existing Public Health Law in that it requires supervision of the health of the individual child. Where the **M.O.H.** is also **S.M.O.** under the Code of Regulations for Public Elementary Schools, 1908, it may be convenient that the annual report which he is required to make in the latter capacity should be issued together with his annual report on the health of his district. In any case, whether the **M.O.H.** is or is not himself the **S.M.O.**, he should state in his annual report what arrangements are in force for the discharge of the duties of the latter office, and for the medical inspection of children in public elementary schools in the district.

Section 132 of the Factory and Workshop Act, 1901, which came into force on January 1st, 1902, requires that "the **M.O.H.** of every District Council shall, in his annual report to them, report specifically on the administration of this Act in workshops and workplaces, and he shall send a copy of his annual report, or so much of it as deals with this subject, to the Secretary of State."

The copy should be addressed to the Secretary of State, Home Office, Whitehall, and the foregoing remarks with respect to the transmission of the report to the **L.G.B.** apply also to its transmission to the Home Office.

The **M.O.H.** is required to report on the administration of the Factory and Workshop Act, 1901, only in so far as this administration is in the hands of the District Council and is concerned with matters in his department. In reporting on the sanitary administration of workshops and workplaces he should include an account of the action with respect to factories, workshops, and workplaces taken under the Public Health Acts as well as under the Factory and Workshop Act.

In reporting on the sanitary condition of workshops and workplaces the **M.O.H.** should state what action has been taken to remedy any defective conditions met with under each heading. He should state whether section 22 of the Public Health Acts (Amendment) Act, 1890, is in force in the district, and what standard of "sufficiency and suitability" of sanitary accommodation is adopted locally.

The report should state, as regards all existing underground bakehouses, whether they comply with the requirements of the should be given in the returns. Arrangements must be made separately for information of the deaths in distant public institutions of residents in the locality.

Birth returns.—Returns should also be obtained from the registrars, at weekly, monthly, or quarterly intervals, of the births registered in such intervals; these returns should distinguish between males and females, and between legitimate and illegitimate births. Under the Notification of Births (Extension) Act, 1915, intimations of births now reach the **M.O.H.** earlier than formerly.

Notification returns.—Compulsory notification of certain infectious diseases, voluntary notification of others, notification from schools, etc., all furnish the Medical Officer with information respecting the occurrence of such disease.

Returns of pauper sickness.—An Order of the **L.G.B.**, dated February 12th, 1879, requires all district and workhouse medical officers appointed after February 28th, 1879, to furnish the **M.O.H.** with returns of pauper sickness and deaths, and to notify the outbreak of any dangerous infectious disease. The same is required (by an Order dated June 14th, 1879) of medical officers of district schools appointed after June 24th, 1879. The Guardians should be asked to instruct their clerk to copy from the district Medical Officer's relief lists the new cases which are reported at each meeting of the Guardians, and to forward the same promptly and regularly to the **M.O.H.**, and to instruct the Poor Law Medical Officers to give to the **M.O.H.** the earliest possible information of cases of dangerous infectious disease under their charge.

Cases of dangerous infectious diseases occurring on canal boats or in common lodging-houses must be reported to the **M.O.H.**, and the **S.A.** have power to make bye-laws requiring notification of such diseases in "tenement" lodging-houses, and in vans or tents.

Weekly returns.—Since January, 1911, the **L.G.B.** have issued a weekly summary of notifiable infectious diseases for the whole country, which is sent to each **M.O.H.** (in response to his fulfilment of Duty No. 13 of Art. XIX., *see* p. 564).

Maps.—A good map is essential. It should show the boundaries of the district, and of each of its sub-divisions (whether parishes, townships, registration sub-districts, special drainage districts, or other) which have a bearing upon sanitary administration, and also the main sewers and water-mains. Maps showing the geology of the district, the contour lines, and the different watersheds should be obtained, if possible. Maps showing the local distribution of disease and mortality have already been referred to.

Periodical reports, etc.—The annual and quarterly reports of the Registrar-General are indispensable. The annual summaries and weekly returns deal only with the statistics of the large towns. The official reports of the Medical Departments of the **L.G.B.**, the Board of Education, and the Home Office are also necessary. Reports of the inspectors of the **L.G.B.** affecting any part of the district should, of course, be obtained, and if the **M.O.H.** be not himself also **S.M.O.** it will be necessary for him to study the reports of the school medical service for his area.

Acts of Parliament.—In addition to any local Acts in force in the district, and all the chief statutes dealing with public health, the **M.O.H.** should be familiar with any other Acts which the special circumstances of his district may render important.*

Bye-laws and regulations.—The bye-laws and regulations in force in the district can readily be obtained, and are not less important than the preceding.

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* Lumley's or Glen's *Public Health Acts*, Glen's *L.G.B. Sanitary Orders*, and the *Model Bye-laws of the L.G.B.* are valuable for reference.

Census data.—The **M.O.H.** should be in possession of all the information regarding his district given by each census taken since its formation. Arrangements should, if possible, be made at the time when the census is taken to obtain a record of the particulars regarding each "enumeration district" for the use of the **S.A.**

Registers.—It is desirable to keep registers showing for each village or hamlet the dates and particulars of every death, and of every notified case of infectious disease. In towns this would take the form of a "street and house register." If cases of disease as well as deaths are entered, they may be distinguished by red ink. Registers of notified diseases have already been referred to. Registers of all deaths occurring among certain trades will greatly facilitate any future investigation which the **M.O.H.** may have to make into the influence of those trades upon mortality.

The seemingly formidable records mentioned above, if well arranged in the first instance, and systematically kept, involve much less labour than would appear at first sight. They are invaluable in inquiries regarding the incidence of mortality and disease upon any given locality or occupation, and materially simplify the preparation of the annual report.

Auxiliary agencies.—In addition to the routine work of the **M.O.H.** there are many auxiliary agencies which may be established in his district or by his **S.A.** which call for more or less of his attention or will prove of service to him in his work; such, for example, are voluntary health societies and children's care committees, the school medical service and school nurses, crèches, infant milk depôts, maternity and infant welfare centres, clinics for children, tuberculosis centres and dispensaries, bacteriological work, chemical analysis, meteorological stations, insurance data from friendly societies or otherwise, reception houses for infectious "contacts," cleansing stations for verminous persons, etc.

Voluntary health societies have proved invaluable, and much work is now undertaken by them and by thousands of "care committees," particularly for the medical supervision of children and juvenile workers.

School medical service (*see* p. 256).

Infants' milk depôts.—It would appear that there are five possible means of supplying a suitable and pure milk for infants: (1) By means of Municipal Milk Depôts similar to institutions at Nancy and Fécamp; (2) by one or more dairymen undertaking to furnish such modified milk (certified) under medical supervision; (3) by obtaining such a supply from dried milk; (4) by means of medical "milk commissions," as in the United States; or (5) by means of a voluntary society supplying such milk under necessary supervision and control.

The French depôts are, broadly speaking, of two types, the "consultation de nourrissons," as at Nancy, and the "goutte de lait," as at Fécamp. The latter is the prototype of the infants' milk depôts established in this country and elsewhere, to succour those infants of the poor for whom breast-feeding is practically impossible. The milk is modified, pasteurized or sterilized, and served in "one-feed" bottles, the amount and kind of modification depending upon the age of the infant. The beneficial effect such milk depôts exert upon infant mortality has been demonstrated repeatedly. It is, of course, essential that the milk should be derived from healthy clean cows, and all the dairying carried out on hygienic principles.

Maternity and child welfare is now provided for under numerous organizations, such as antenatal clinics for expectant mothers, maternity centres and hospitals, baby clinics and dispensaries, crèches and day nurseries, nursery schools, "schools for mothers," and a variety of forms of health visitation.

Bacteriological laboratories.—The great value of early and accurate diagnosis in such diseases as tuberculosis, diphtheria, anthrax, enteric fever, and of the bacteriological investigation of water, milk, cheese, of sewage and its effluents, of air, etc., has now become generally recognized, with the result that a Public Health Department is not considered fully equipped unless it is provided with facilities for bacteriological research, either by establishing a municipal laboratory or by utilizing a private laboratory such as those in connexion with hospitals and medical schools. Facilities should be provided for the free examination of any materials from infectious cases submitted by medical men, and for the provision of prophylactic serum or vaccine.

Meteorological records (*see* Chap. II.).

Duties of Sanitary Inspectors.—The work of the Sanitary Inspector (or "Inspector of Nuisances") is closely connected with that of the **M.O.H.**, but the broad lines separating them will be apparent from the following definition of the inspector's duties, formulated by the **L.G.B.**, November, 1910:—

1. Subject to the directions of the Council, he shall perform, under the general supervision of the **M.O.H.**, all the duties specially imposed upon an Inspector of Nuisances by the Public Health Act, 1875, or by any other statute or statutes, or by the orders issued by the **L.G.B.**, so far as the same apply to his office.

2. He shall attend all meetings of the Council, or of committees of the Council, when so required.

3. He shall by inspection of his district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed in respect of the nuisances existing therein that require abatement.

4. On receiving notice of the existence of any nuisance within his district, or of the breach of any bye-laws or regulations made by the Council for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of bye-laws or regulations.

5. He shall report to the Council any noxious or offensive businesses, trades, or manufactories established within his district, and the breach or non-observance of any bye-laws or regulations made in respect thereof.

6. He shall report to the Council any damage done to any works of water supply, or other works belonging to them, and also any case of wilful or negligent waste of water supplied by them, or any fouling, by gas, filth, or otherwise, of water used or intended to be used for domestic purposes.

7. He shall from time to time, and forthwith upon complaint, visit and inspect the shops and places kept or used for the preparation or sale of butchers' meat, poultry, fish, fruit,

vegetables, corn, bread, flour, milk, or any other article to which the provisions of the Public Health Acts in this behalf apply, and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, milk, or other article as aforesaid, which may be therein; and in case any such article appear to him to be intended for the food of man, and to be unfit for such food, he shall cause the same to be seized, and take such other proceedings as may be necessary in order to have the same dealt with by a justice. He shall also take such action as it may be necessary for him to take by virtue of the provisions of the Public Health (Regulations as to Food) Act, 1907, and any regulations made thereunder: provided that, in any case of doubt arising under this paragraph, he shall report the matter to the **M.O.H.**, with the view of obtaining his advice thereon.

8. He shall, when and as directed by the Council, procure and submit samples of food, drink, or drugs, suspected to be adulterated, to be analysed by the analyst appointed under the Sale of Food and Drugs Act, 1875, and upon receiving a certificate stating that the articles of food, drink, or drugs are adulterated, cause a complaint to be made, and take the other proceedings prescribed by that Act.

9. He shall give immediate notice to the **M.O.H.** of the occurrence within his district of any infectious or epidemic disease; and whenever it appears to him that the intervention of such officer is necessary, in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall forthwith inform the **M.O.H.** thereof.

10. He shall, subject to the directions of the Council, attend to the instructions of the **M.O.H.** with respect to any measures which can be lawfully taken by an Inspector of Nuisances under the Public Health Act, 1875, or under any other statute or statutes, or under any regulations issued by the **L.G.B.** for preventing the spread of any infectious or epidemic disease.

11. He shall enter from day to day, in a book to be provided by the Council, particulars of his inspections, and of the action taken by him in the execution of his duties. He shall also keep a book or books, to be provided by the Council, so arranged as to form as far as possible a continuous record of the sanitary condition of each of the premises in respect of which any action has been taken under the Public Health Act, 1875, or under any other statute or statutes, or under any regulations issued by the **L.G.B.**, and shall keep any other systematic records that the Council may require.

12. He shall, at all reasonable times, when applied to by the

M.O.H., produce to him his books, or any of them, and render to him such information as he may be able to furnish with respect to any matter to which the duties of Inspector of Nuisances relate.

13. He shall, if directed by the Council to do so, superintend and see to the due execution of all works which may be undertaken under their direction for the suppression or removal of nuisances within his district.

14. He shall, if directed by the **M.O.H.** to do so, remove, or superintend the removal of, patients suffering from infectious disease to an infectious diseases hospital, and shall perform, or superintend, the work of disinfection after the occurrence of cases of infectious disease.

15. He shall, if directed by the Council to do so, act, as officer of the Council, as local Authority under the Diseases of Animals Acts, 1894 to 1909, the Canal Boats Acts, 1877 and 1884, and under any Orders or Regulations made thereunder.

16. He shall, as soon as practicable after the 31st of December in each year, furnish the **M.O.H.** with a tabular statement containing the following particulars: (*a*) the number and nature of inspections made by him during the year; (*b*) the number of notices served during the year, distinguishing statutory from informal notices; (*c*) the result of the service of such notices.

17. In matters not specially provided for in this Order, he shall observe and execute any orders and directions which may be hereafter issued by the **L.G.B.**, and the lawful orders and directions of the Council, applicable to his office.

The above statements of duties of Medical Officers and Sanitary Inspectors are general, and are incorporated in "The Sanitary Officers (Outside London) Order, 1910." Further details must be sought in the Acts, Orders, Bye-laws, and Regulations, and in the instructions of the **S.A.** affecting these officers. It is competent for the **S.A.** to specialize the work of Sanitary Inspectors (e.g. inspection of meat or workshops), or to appoint women in that capacity.

In districts possessing a population of 10,000 it is generally desirable that a whole-time Sanitary Inspector should be appointed. In order to secure such an appointment the following offices may be conveniently combined with that of Sanitary Inspector: Surveyor under Public Health Act (except in districts where building operations are very active), Inspector under Infant Life Protection Act, Inspector under Shop Hours Acts, Assistant Officer under Unsound Food Regulations, Superintendent of Scavenging, etc. It is not usually desirable to combine the office of Surveyor of Highways with that of Sanitary Inspector. In the case of small districts a combined appointment of Sanitary Inspector may be made.

CHAPTER XVIII

SANITARY LAW

UNDER this heading it is proposed to give a summary of the principal Acts of Parliament bearing upon public health in general, reserving for consideration in later chapters industrial legislation and local bye-laws.

As elsewhere in this volume, **S.A.** stands for Sanitary Authority, **L.G.B.** for Local Government Board, and **M.O.H.** for Medical Officer of Health.

Public Health Act, 1875.—The whole of England and Wales, except London, consists of Urban and Rural Sanitary Districts, under the jurisdiction respectively of Urban and Rural **S.A.s** (s. 5), which, in pursuance of the Local Government Act of 1894, are now termed Urban and Rural District Councils. That portion of the area of a Union which is not included in any Urban District constitutes a Rural Sanitary District, and the Guardians representing that part of the Union are the Rural **S.A.** (s. 9).

Sewers, except certain private sewers, are vested in the **S.A.** of the district (s. 13). The **S.A.** may purchase (s. 14) or construct (s. 15) sewers. They must provide such sewers as are necessary for effectually draining their district (s. 15). Powers are given by s. 27 for the treatment and disposal of sewage. The sewers must be so constructed, covered, ventilated, and kept as not to be a nuisance or injurious to health, and must be properly cleansed (s. 19).

House drainage.—If any house is without a sufficient drain the **S.A.** *must* require the owner or occupier to provide a drain, and may prescribe the materials, size, and levels. This drain must lead to the public sewer if there be any within 100 ft. of the site of the house ; if not, to a covered cesspool in such position (not under a house) as the **S.A.** may direct. Failing compliance, the Authority may carry out the works. No house in an urban district must be built or occupied until proper covered drains have been constructed to the satisfaction of the **S.A.** The **S.A.** may make regulations as to the mode in which connexions between drains and sewers are to be made. Upon giving due notice, and complying with such regulations, the owner of any premises is entitled to carry drains into the public sewers (ss. 21–25).

Excrement and refuse disposal.—It is unlawful to erect any house without a sufficient water-closet, earth-closet, or privy, and an ashpit with proper doors and coverings, and the same must be provided for any existing house on the order of the **S.A.**, who may require a separate closet for each house (ss. 35–36). The **S.A.** may order the provision of separate closets for each sex in factories and workshops where both sexes are employed (s. 38) ; this applies also to above-ground parts of coal-mines if women and girls are employed (Coal Mines Regulation Act, 1872, s. 74). The corresponding parts (pit-banks) of metalliferous mines are factories or workshops. Urban **S.A.s** may provide public closets, urinals, or receptacles for refuse (ss. 39, 45). Every **S.A.** must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (s. 40).

On written complaint that any drain, closet, ashpit, or cesspool is a nuisance, the **S.A.** may authorize their officer to enter the premises (after giving twenty-four hours' notice, except in case of emergency) and open the ground ; if any defect is found, the **S.A.** must serve notice upon the owner or occupier; but if there be no defect, the **S.A.** must close the ground and make good any damage.

Scavenging and cleansing.—The **S.A.** *may*, and when required by order of the **L.G.B.** *shall*, themselves undertake or contract for the removal of house refuse, the cleansing of earth-closets, privies, ashpits, and cesspools, and the cleansing of streets (s. 42). In that case they are liable to penalty for any delay exceeding seven days after written notice from any householder.

Cleansing of houses.—If the **M.O.H.** or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing, cleansing, or purifying thereof would tend to prevent infectious disease, the **S.A.** may require the owner or occupier to cleanse, etc., and in his default may themselves do what is necessary (s. 46).

It is unlawful in an urban district to keep swine in any dwelling-house, or so as to be a nuisance, or to suffer any waste water to remain within any dwelling-house for twenty-four hours after written notice from the **S.A.**, or to allow the contents of any water-closet, privy, or cesspool to overflow or soak therefrom. In case of default, the **S.A.** must abate such nuisance (s. 47).

An inspector of nuisances in an urban district may give notice to the owner of any accumulation of offensive matter, or to the occupier of the premises whereon it exists, and if not removed within twenty-four hours, it becomes vested in the **S.A.** to be disposed of by them (s. 49). An urban **S.A.** may give public notice requiring the periodical removal of manure or other refuse matter from stables or other premises and enforce the same under penalty (s. 50).

Water supply.—Any **S.A.** may* construct works for supplying any part of their district with water; or may hire or purchase such works, or contract for a supply (s. 51); and may require houses to be supplied with water when they are without a proper supply, if it can be furnished at a cost not exceeding the water-rate authorized by any local Act, or twopence a week, or such other cost as the **L.G.B.** may, upon application, determine to be reasonable in the circumstances (s. 62).

Heavy penalties are incurred by persons polluting any stream, pond, etc., with gas washings (s. 68), and a local Authority may proceed against anyone polluting any watercourse with sewage (s. 69). A Justice's order may be obtained for the closing of a well or cistern the water of which is used, or likely to be used, for drinking or domestic purposes, when the water is so polluted as to be injurious to health, and the Court may cause the water to be analysed at the cost of the **S.A.** (s. 70).

Cellar dwellings.—No cellar built or rebuilt since 1848 (the date of a previous Act) can be separately occupied as a dwelling; nor any cellar whatever, unless it comply with the following requirements:—

(*a*) The height must in every part be at least 7 ft., 3 ft. of which must be above the level of the adjoining street. (*b*) *An open area at least 2½ ft. wide in every part, and 6 in. below the level of the floor, must extend along the whole frontage. It may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 ft. below the floor. (*d*) There must be proper closet and ashpit accommodation. (*e*) There must be a fire-place and chimney, and (*f*) a window at least 9 sq. ft. in area, made to open. The window of a back cellar let or occupied along with a front cellar need only be 4 sq. ft. in area (ss. 71–3).

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* The wording here is permissive; but *see* p. 191.

Anyone passing the night in a cellar is deemed to occupy it (s. 74).

Common lodging-houses.*—The **S.A.** are required to keep a register of common lodging-houses, and to make bye-laws in respect of them (ss. 76–80). It is unlawful to keep a common lodging-house unless it be registered (s. 77), and this can only be done after it has been inspected and approved (s. 78). The keeper, when required, is to affix notice of registration to the house.

When the lodging-house is without a proper supply of water, and this can be furnished at a reasonable rate, the **S.A.** may enforce it (s. 81). The keeper is required to limewash the walls and ceilings in the first week of April and October of every year (s. 82). The **S.A.** may require the keeper of a house in which beggars or vagrants are received, to make returns of persons who have slept there the previous night (s. 83), and the keeper must always give notice to the **M.O.H.** and to the Relieving Officer of any case of infectious disease (s. 84).

Houses let in lodgings.—Any **S.A.** may make bye-laws respecting houses let in lodgings or occupied by members of more than one family (s. 90, modified by s. 8 of the Housing of the Working Classes Act, 1885).

Nuisances.—(s. 91.) The following are nuisances:—(1) Any premises † in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, or watercourse, privy, urinal, cesspool, rain,* or ashpit so foul or in such a state as to be nuisance or injurious to health. (3) Any animal o kept as to be a nuisance or injurious to health. 4) Any accumulation or deposit which is a nuisance r injurious to health.† (5) Any house,‡ or part of house, so overcrowded as to be dangerous or in-urious to the health of the inmates, whether or ot members of the same family. § (6) Any workshop, workplace, or domestic factory, not kept in a cleanly tate, or not ventilated in such a manner as to render armless as far as practicable any gases, vapours, ust, or other impurities generated in the course of the work carried on therein that are a nuisance r injurious to health, or so overcrowded as to be angerous or injurious to the health of those em-ployed therein. || (7) Any fire-place or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever; and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.¶

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* Lodging-houses in which persons of the poorer class are received for short periods, and, though strangers to each other, are allowed to inhabit one common room. The term does not cover inns, or lodgings let to the middle or upper classes. In London there are Common Lodging Houses Acts, 1851–8, in force, incorporating similar powers.

† Including *buildings* or *lands*.

* "'Drain' means any drain of and used for the drainage of one building only, or premises within the same curtilage . . . ." A sewer is a drain receiving the drainage of two or more buildings.

† There is no penalty if the accumulation or deposit is necessary for, and has not been kept longer than is necessary for, the carrying on of any business or manufacture, and if the best available means have been taken for preventing injury to the public health.

‡ Including schools, and also workshops and other buildings in which persons are employed. *Domestic* factories also are included.

§ It is customary to adopt the standards of the Model Bye-laws, viz. 300 cub. ft. per head, counting two children as one adult; but for work-shops and workplaces, *see* p. 672. In the event of a second conviction for overcrowding within three months, the Court may order the closing of the premises for any period (s. 109).

|| The provisions of this subsection apply to all buildings except such as are subject to the special provisions, relating to cleanliness, ventila-tion, or overcrowding, of the Factory and Workshop Act.

¶ There is no penalty if the Court is satisfied that such fire-place or furnace is constructed in such manner as to consume as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fire-place or furnace has been carefully attended to by the person having the charge thereof.

Later Acts have extended this definition. Thus workshops or workplaces not kept free from effluvia arising from any drain, closet, or other nuisance (Factory Act, 1901, s. 2); workshops in any room of which sufficient ventilation is not provided and maintained, or in which the processes carried on render the floor wet, and the floor is not adequately drained (Factory Act, s. 78—*see also* p. 668); tents or vans so filthy or overcrowded as to be a nuisance or injurious to health (Housing Working Classes Act, 1885, s. 9), and unfenced quarries (Quarry Fencing Act, 1887, s. 3) or unfenced shafts of disused metalliferous mines (Metalliferous Mines Regulation Act, 1872, s. 13) within 50 yards of a highway, are nuisances under s. 91, 1875. (*See also* Public Health Amendment Act, 1907, s. 35.)

Procedure in respect of nuisances.—It is (1) the duty of the **S.A.** to cause to be made from time to time an inspection of their district, to ascertain what nuisances exist, but (2) the **S.A.** may be put in motion by any person aggrieved, or by any two householders or by any officer of the **S.A.**, or by the Relieving Officer, or by any officer of the Police. (3) If satisfied as to the existence of a nuisance, the **S.A.** must serve a notice on the person responsible, or, if he cannot be found, on the owner or occupier, requiring him to abate it, and to execute such works and do such things as may be necessary. Where the nuisance arises from the want or defect of any structural convenience, or where there is no occupier, notice must be served on the owner. If the person causing the nuisance cannot be found, and the owner or occupier is not responsible, the local Authority may abate the nuisance. (4) If the person on whom the notice is served fails to comply, or if the nuisance, although abated, is likely to recur, the **S.A.** may apply to a Justice, who shall summon the person responsible, and may make an order requiring compliance or prohibiting the recurrence of the nuisance, and directing the execution of any works necessary. The Court may further impose a penalty (ss. 92–96). Where the nuisance is such as to render the house unfit for habitation, the Court may order the house to be closed, and may rescind this by a further order when satisfied that the house has been made fit for habitation (s. 97). Any person not obeying the order of the Court, or failing to use due diligence, is liable to penalty; and the **S.A.** may carry out the order and charge him with the expenses (s. 98). Where the person responsible for the nuisance cannot be found, the order of the Court may be executed by the **S.A.** Any matter or thing removed by the **S.A.** in abating any nuisance may be sold. Where a nuisance within a district is caused by some act or default beyond its limits, the **S.A.** may, nevertheless, institute proceedings (s. 108).

Ships.—Any ship or vessel lying in any water within the district of any **S.A.** is subject to their jurisdiction, as if it were a house.* If in any other water, it is deemed to be within such district as may be prescribed by the **L.G.B.**, and in the absence of such prescription, then within the nearest district (s. 110).

Right of entry upon private premises. — The **S.A.** and their officers have rights of entry between 9 a.m. and 6 p.m., and in the case of a nuisance arising in respect of any business, at any hour when such business is in progress. If admission be refused, a Justice's order may be obtained (ss. 102 and 103).

Offensive trades.—It is illegal to establish an offensive trade within the district of an urban **S.A.** without their consent. The offensive trades are: blood-boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, tripe-boiler, any other noxious or offensive trade, business, or manufacture (s. 112). An urban **S.A.** may make bye-laws with respect to such trades as have been established with their consent,* to prevent or diminish nuisance arising therefrom (s. 113). If the **M.O.H.**, or two medical practitioners, or ten inhabitants, certify that any of the premises named below are a nuisance, or injurious to health, the **S.A.** must take proceedings against the offender, who is liable to penalty unless he can show that he has used the best practical means for abating such nuisance, or preventing or counteracting such effluvia. The premises in question are : candle-house, melting - house, melting - place, soap - house, slaughter-house, any building or place for boiling offal or blood, or for boiling, burning, or crushing bones, or any manufactory, building, or place used for any trade, business, process, or manufacture, causing effluvia (s. 114). The same powers are applicable in the case of nuisances affecting the inhabitants of a district, but resulting from premises situated beyond the limits of the district.

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* This section originally brought ships under those provisions of the Act that relate to *nuisances* only; but the Public Health (Ships) Act, 1885, extended its scope to include also infectious diseases and hospitals (ss. 120, 121, 124, 125, 126, 128, 131, 132, and 133).

[As regards the prohibition (s. 112) of the establishment of any given trade without the consent of the **S.A.**, it is incumbent upon the prosecuting authority to show that the trade is either one of those specifically mentioned above, or *ejusdem generis* with them; that is, that it is necessarily an offensive trade apart from neglect or mismanagement. The higher Courts have held that this is the case with rag-and-bone stores for example, but not with brick-making, manure works, or fish-frying. Nevertheless, a very large number of trade processes to which the above restriction may be considered inapplicable will come within the scope of s. 114, if it can be shown that they are carried on so as to give rise to effluvium nuisances.]

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* As this consent only became necessary in 1848, the bye-laws can only apply to trades established since that date.

Unsound food.—The **M.O.H.** or Inspector of Nuisances may, at all reasonable times, examine any animal,* carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, exposed for sale, or deposited for the purpose of sale, or of preparation for sale, and intended for the food of man; and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate, who may order it to be destroyed, and inflict a penalty upon the offender. The proof that it was not intended for the food of man rests with the person charged (ss. 116, 117). Any person obstructing is subject to penalty (s. 118). On complaint made on oath a Justice may grant a search warrant to the **M.O.H.** or Inspector.

[Eggs, butter, cheese, and other important articles of food are not mentioned specifically, and are therefore not included in the scope of the Act. No proceedings can be taken in regard to articles already sold. Both these defects are avoided in the Public Health Acts Amendment Act of 1890, and in the Public Health (London) Act, 1891.]

Infectious diseases. — Upon the certificate of the **M.O.H.** or other medical practitioner that the cleansing and disinfecting of any house or part thereof, and of any articles therein, would tend to prevent infectious diseases, it is incumbent on the **S.A.** to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A penalty is incurred by default, and the **S.A.** may do what is necessary and recover the costs, or may undertake this duty in the first instance, with the consent of the occupier, at their own cost (s. 120). The **S.A.** may destroy infected bedding, clothing, or other articles, and give compensation (s. 121); may provide a disinfecting apparatus and disinfect free of charge (s. 122); may provide an ambulance and pay expenses of conveyance of any infectious persons to hospital (s. 123).

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* Living animals may be seized under this section.

Where a hospital is provided within convenient distance, a Justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or lodged in a room occupied by more than one family,* or is on board any ship or vessel (s. 124). The **S.A.** may make regulations for removing to any available hospital, and for keeping there as long as necessary, any persons brought within their district by vessel who are infected with a dangerous infectious disorder (s. 125).

It is unlawful for any person so suffering to expose himself wilfully, without proper precautions against spreading the disorder, in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously notifying to the owner, conductor, or driver thereof that he is so suffering; or, being in charge of any person so suffering, to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which have been exposed to infection from any such disorder; but this does not apply to the transmission with proper precautions of articles for the purpose of having them disinfected (s. 126). The owner or driver of a public conveyance so used is required under penalty to have the same immediately disinfected, but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him (s. 127). Any person who knowingly lets for hire any house, or room, in which any person has suffered from such disorder, without having it and the contents disinfected to the satisfaction of a medical practitioner as testified by a certificate signed by him, is liable to penalty (s. 128). Any person letting or offering for hire any house, or part of a house, who on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such question, becomes liable to penalty or imprisonment (s. 129).

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* This detail is omitted as superfluous in the London Act of 1891; but lodgment in a tent or van is made *per* [illegible] a reason for removal.

Special regulations of L.G.B.—The **L.G.B.** may make regulations for the treatment of persons affected with cholera, or any other epidemic, endemic, or infectious diseases, and for preventing the spread of such diseases as well on the seas, rivers, and waters of the United Kingdom, and on the high seas within three miles of the coast thereof, as on land, and may declare by what Sanitary Authorities such regulations shall be enforced and executed (s. 130). Cholera Regulations have been issued under this section (p. 541).

Furthermore, whenever any part of England appears to be threatened with, or is affected by, any formidable epidemic, endemic, or infectious disease, the **L.G.B.** may make, and from time to time alter or revoke, regulations for any of the following purposes, viz.: for the speedy interment of the dead, for house-to-house visitation, for the provision of medical aid and accommodation, for the promotion of cleansing, ventilation, and disinfection, and for guarding against the spread of disease; and may by order declare all or any of the regulations so made to be in force within the whole or any part of the district of any **S.A.**, and to apply to any vessels whether on inland waters or on parts of the sea within the jurisdiction of the Lord High Admiral of the United Kingdom (s. 134). The **S.A.s** are required to do everything that is necessary to carry out these regulations.

Hospitals.—Any **S.A.** may build or contract for the use of hospitals for their district. Two or more **S.A.s** may combine for this purpose (s. 131). The **S.A.** may recover from a patient, who is not a pauper, the cost of his maintenance (s. 132). The **S.A.** may with the sanction of the **L.G.B.** themselves provide or contract for a temporary supply of medicine and medical assistance for their district (s. 133). (*See also* Isolation Hospitals Acts, pp. 281–3.)

Mortuaries.—Every **S.A.** *may*, and, if required by the **L.G.B.**, *must*, provide a mortuary, and may make bye-laws with respect to its management and charges for its use. They may also provide for the decent and economical interment, at charges to be fixed by such bye-laws, of any dead body which may be received into a mortuary (s. 141). A Justice may, on a certificate signed by a practitioner, order to be removed to a mortuary, at the cost of the **S.A.**, (1) the body of anyone who has died of any infectious disease, and which is retained in a room in which persons live or sleep, or (2) any dead body which is in such a state as to endanger the health of the inmates of the house or room in which it is retained. He may direct the same to be buried within a specified time. If the friends fail to comply, it is the duty of the Relieving Officer to bury, and the expenses may be recovered from the proper person (s. 142). The **S.A.** may provide a place for the post-mortem examination ordered by a coroner.

New streets and buildings.—In urban districts all public streets (*i.e.* those reparable by the inhabitants at large) are vested in the **S.A.**, who *shall* cause them to be levelled, paved, and repaired, as occasion may require (s. 149). The owners of property abutting on any private street or part of a street may be required by the (urban) **S.A.** to level, pave, sewer, light, or make good such street or part of a street; and in case of default the **S.A.** may carry out the work and recover the expenses from the owners according to the frontage of their respective premises (s. 150). An urban **S.A.** may make bye-laws with regard to new streets and buildings. For the purposes of the Act the re-erection of any building pulled down to or below the ground floor, or the conversion into a dwelling-house of any building not originally constructed for human habitation, or the conversion into more than one dwelling-house of a building originally constructed as one dwelling-house only, shall be considered the erection of a new building (s. 159).

Dangerous structures.*—The surveyor of an urban **S.A.**, if satisfied that any building or wall is in a ruinous state so as to be dangerous to passengers or to the inmates of neighbouring houses, shall cause a fence to be put up, and shall order the owner forthwith to secure or pull down such building; and in default thereof the surveyor may obtain a Justice's order to carry out the necessary works, and may recover the expenses. (Towns Improvement Clauses Act, ss. 75-78, incorporated with the Public Health Act by s. 160 of the latter.)

Rain-pipes and eaves-gutters.—An urban **S.A.** may compel the owner of any building adjoining or near to a street to provide within seven days efficient eaves-gutters and rain-pipes. (Towns Improvement Clauses Act, s. 74; Public Health Act, s. 160.)

Slaughter-houses.—An urban **S.A.** may provide abattoirs or slaughter-houses, and if they do so must make bye-laws with respect to management and charges (s. 169). They may also license slaughter-houses and knackers' yards, and without their licence no place shall be used for such purposes which was not so used at the time of the passing of the Act, i.e. in 1875. Every place used as a slaughter-house or knacker's yard shall be registered by the owner or occupier in a book kept by the **S.A.** An urban **S.A.** *must* make bye-laws in regard to slaughter-houses and knackers' yards. If any person is convicted of killing or dressing any cattle contrary to the provisions of the Public Health Act, or of the non-observance of any of the bye-laws or regulations made under this Act, the Justices before whom he is convicted may suspend the licence for two months or less, and in the event of a second offence may revoke the licence. (Sections 125–130 Towns Improvement Clauses Act, incorporated in the Public Health Act by virtue of s. 169.)

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* These and some of the following provisions are not to be found in the text of the Public Health Act, but in the incorporated portion of the Towns Improvement Clauses Act.

A legible notice bearing the words Licensed Slaughter-House or Registered Slaughter-House must be attached and maintained in some conspicuous place on every registered slaughter-house by the owner or occupier (s. 170).

Combination of Sanitary Authorities for appointment of M.O.H.—The **L.G.B.** may (compulsorily or otherwise) unite two or more districts situated wholly or partially in the same county, for the purpose of appointing a **M.O.H.**; but no urban district with more than 25,000 inhabitants shall be included without the consent of the **S.A.**, and in the event of any **S.A.** objecting to being included, the **L.G.B.** can only include their district by means of Provisional Order subject to confirmation by Parliament (s. 286).

A **S.A.** may delegate all or any of their powers to a committee of their own members (ss. 200 and 201);

and a rural Authority may form parochial committees consisting wholly or partially of their own members, and may give to such committees certain limited sanitary functions (s. 202). (*See* p. 614.)

Urban powers for rural districts.—The **L.G.B.** may give to a rural **S.A.**, as regards the whole or part of their area, any powers and responsibilities conferred by this Act upon urban **S.A.s** (s. 276).

Special drainage districts.—A rural **S.A.** may, with the consent of the **L.G.B.**, constitute any portion of their area a special drainage district for the purpose of charging thereon exclusively the expenses of works of sewerage, water supply, or other works which may be declared by the **L.G.B.** to be special expenses, and thereupon such area shall become a separate contributory place (s. 277). The **S.A.** have also power to declare expenses which they have incurred to be private improvement expenses, and to charge a special private improvement rate in respect thereof upon the estate benefited (ss. 213 and 232).

Union of districts for sanitary purposes.—Joint boards may be formed; by order of the **L.G.B.**, for the purpose of water supply or sewerage, or for other purposes of the Public Health Act, as applied to a district comprising the whole or parts of two or more sanitary districts (s. 279). Under this section joint Hospital Boards may be formed.

Default of S.A.—If satisfied, after due inquiry, that any **S.A.** have made default in providing or maintaining sewers, or in providing and maintaining a supply of pure water,* or in enforcing any provisions of the Public Health Act which it is their duty to enforce, the **L.G.B.** shall make an order limiting a time for the performance of their duty in the matter.

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* "In cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply of water, and a proper supply can be got at a reasonable cost."

If such duty is not performed in the time allowed, the order may either be enforced by writ of mandamus, or the **L.G.B.** may appoint some person to perform the work, and charge all expenses to the Authority in default (s. 299).

[The 7th section of the Housing of the Working Classes Act, 1885, has a wider scope.]

Port Sanitary Authority.—The **L.G.B.** may, by order, constitute any **S.A.** whose district abuts upon any port in England the **S.A.** for the whole or for any part of such port. The Board may also combine two or more riparian Authorities for the purpose; or may constitute one Port **S.A.** for any two or more ports. The Authority may be constituted permanently or temporarily. The order constituting the Authority may assign to it any of the powers or duties of an urban **S.A.** so far as applicable to a Port **S.A.**, and to vessels, waters, or persons within its jurisdiction. —namely, under ss. 91–111 (nuisances), 120–133 (infectious diseases and hospitals), 134-138 (prevention of epidemic diseases), 141–142 (mortuaries), 182–186 and 188 (bye-laws), 189 (appointment of **M.O.H.** and Inspector of Nuisances), and other sections.*

The **Public Health Act, 1896,** repeals the old Quarantine Act of 1825, and extends the powers of the **L.G.B.** to make orders under ss. 130 and 134 of the 1875 Act, dealing with epidemic, endemic, or infectious diseases. Accordingly (*see* p. 541), regulations as to cholera, yellow fever, and plague were issued in an Order dated 1896, and renewed September 9th, 1907.

The **Public Health (Ports) Act, 1896,** enables the **L.G.B.** to issue orders making all or any of the provisions of the Infectious Diseases Prevention Act, 1890, applicable to any Port Sanitary Authority.

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* The powers and duties of a Port **S.A.** and its officers consist primarily of those conferred by such of the specified portions of the Public Health Act as the particular Order may decide. They are extended by the Cholera Regulations (p. 541), and the Order prescribing the duties of the Port **M.O.H.** A ship comes within the definition of "house" for many purposes.

The **Public Health Acts Amendment Act, 1890,** is an "adoptive" Act, of which Part III. is concerned with sanitary matters. Urban **S.A.s** may by resolution adopt any part of the Act; rural Authorities can adopt those powers which are not expressly limited to urban districts, and, as regards the rest, can apply to the **L.G.B.** for full urban powers in the same manner as under the 1875 Act. The following are the chief provisions of Part III. :—

Sewers.—It is unlawful to pass into any drain or sewer (*a*) any substance which may injure it or impede the flow of its contents; or (*b*) any chemical refuse, or waste steam, or water or other liquid heated above 110° F., which either alone or in combination with sewage causes a nuisance or is dangerous to health.

Closets, etc.—Where any sanitary convenience is used in common by the occupants of two or more houses, any person fouling or injuring it is liable to penalty; and if nuisance arises from want of cleanliness of any part of it or of the approaches, each of the persons having the right of use is liable to penalty, in the absence of proof as to which of them is in default. Sufficient and suitable sanitary conveniences must be provided in all factories and workshops; with separate accommodation for each sex, where persons of both sexes are employed (s. 22).

Bye-laws.—Urban **S.A.s** may make bye-laws respecting public sanitary conveniences provided by them. Section 157 of the 1875 Act is extended so as to enable any urban **S.A.** to make further bye-laws concerning new buildings, upon the following points: (*a*) adequate water supply to closets; (*b*) construction of floors, hearths, and staircases; (*c*) height of rooms intended for habitation; (*d*) paving of yards and open spaces in connexion with houses; (*e*) provision of secondary approaches to houses, for the purpose of removing refuse. It is further provided that bye-laws respecting closets and drainage may be made applicable to old as well as new houses. Similar power of framing bye-laws respecting buildings (under s. 157 as amended) is given to rural **S.A.s**, but with certain exceptions. [Apart from this the **L.G.B.** can, as already stated, grant full urban powers to rural Authorities.] Any **S.A.** may make bye-laws to prevent buildings erected in accordance with bye-laws from being altered in such a way that if at first so constructed they would have contravened the bye-laws.

An urban **S.A.** may make bye-laws respecting the carriage through the streets of offensive matter or liquid, prescribing (*a*) certain hours for such removal, (*b*) proper construction and covering of the receptacle used for the removal, and (*c*) the cleansing of any place fouled by matters dropped or spilled.

Any **S.A.**, themselves undertaking or contracting for the removal of house refuse, may make bye-laws imposing upon the occupier duties in connexion with such removal.

Polluted sites.—No new building may be erected upon ground impregnated with animal or vegetable matter, or upon which such matter has been deposited, unless such matter has been properly removed or has become innocuous. If (in an urban district) any portion of a room is immediately over any privy (not being a water-closet or earth-closet), cesspool, midden, or ashpit, it is illegal to occupy it, or suffer it to be occupied, as a dwelling-place, sleeping-place, workroom, or place of business.

Cleansing of common passages.—If in an urban district any private court or passage, leading to the back of several buildings separately occupied, is not regularly and effectually swept and kept clean, the

S.A. may cause it to be swept and cleaned, and recover the expenses from the occupiers.

Pollution of streams by solid refuse.—It is forbidden "to throw or place . . . . in any . . . . watercourse, within any district in which this part of this Act is adopted, any cinders, ashes, bricks, stone, rubbish, dust, filth, or other matter which is likely to cause annoyance."

Food.—Sections 116–119 of the 1875 Act are extended so as to apply to "all articles intended for the food of man, sold or exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale." A Justice may condemn any such article and order it to be destroyed, if satisfied that it is diseased, unsound, unwholesome, or unfit for the food of man, even if it has not been formally seized under s. 116.

Slaughter-houses.—Licences granted after the adoption of this Act are to remain in force only for such period, not being less than a year, as the **S.A.** shall specify in the licence. Every change of occupation of a licensed slaughter-house must (under penalty) be notified in writing to the Inspector of Nuisances; and notice of this requirement must be endorsed on all new licences. If the occupier of any licensed slaughter-house is convicted under ss. 116–119 of the 1875 Act, the Court may revoke the licence.

Common lodging-houses.—A penalty is imposed upon the keeper if he fails to give notice of any case of infectious disease, as required by s. 84 of the 1875 Act.

The Act does not apply to London.

The **Public Health Acts Amendment Act, 1907**, is also an "adoptive" Act in the sense that **S.A.s** may apply to the **L.G.B.** to make an Order for its enforcement as regards Parts I.—VI. The Act does not apply to London. Parts VII. (Police), VIII. (Fire Brigade), and IX. (Sky Signs) are enforce-able by the Home Secretary. Part I. deals with the general application of the Act. Part II. concerns streets and buildings, and provides for deposit of plans, means of access, repairs, enclosing dangerous places, fencing lands, renaming, temporary buildings, etc. The only strictly sanitary clause in this Part is for the effectual paving and drainage of subsoil or surface of yards of dwelling-houses.

Part III. contains the chief sanitary provisions. S. 35 adds to the nuisances enumerated in the Public Health Act, 1875, any cistern used for the supply of water for domestic purposes so placed, constructed, or kept as to render the water therein liable to contamination likely to cause risk to health; any gutter, drain, shoot, or stack-pipe so defective as to cause dampness to a building; and any deposit of material in or on any building or land which shall cause a dampness dangerous or injurious to health. Rain-water-pipes must not be used as soil-pipes (s. 36), nor must water- or stack-pipes be used as ventilating shafts (s. 37). S. 39 deals with the provision of sufficient and proper water-closet and slop-closet accommodation in new and old buildings, and power is given to **S.A.s** to require the provision of urinals to public-houses and similar establishments. On report of defective or suspicious drainage, tests may be applied (except the water test), subject to consent of owner or occupier, or by order of a Court of summary jurisdiction, and provision is made for filling up old cesspools. The **S.A.** may provide and maintain public sanitary conveniences in or under streets. By s. 48 the Authority must remove trade refuse if required by owners or occupiers so to do.

Various new powers are given in Part IV. as to infectious diseases. If any person knows that he is suffering from an infectious disease he may not engage in any industrial occupation unless he can do so without risk of spreading infection. If the **M.O.H.** certifies to the **S.A.** that milk is suspected of conveying infection, the **S.A.** may require the dairyman to furnish a list of sources of his milk supply, for which he shall be paid 6d. for every 25 names. Every dairyman shall notify to the **S.A.** the occurrence of all cases of infectious disease among his servants. Infected clothes may not be sent, unless disinfected, to a public laundry. S. 57 provides that no child suffering from infectious disease or who has been exposed to infection shall, after notice from the **M.O.H.**, be sent to school without a certificate from the **M.O.H.**, and if the **S.A.** require it the head teacher of a school shall furnish (for 6d. per 25 names) a complete list of the names and addresses of the scholars in a school in which any scholar is suffering from an infectious disease. Persons suffering from infectious diseases shall not use any book from a public library or enter any public vehicle; in the latter case both patient and driver being held responsible. If any public vehicle be so used it must be disinfected. Extended powers for cleansing and disinfecting premises are also given; for the management of common lodging-houses; for the provision of recreation grounds; for policing streets; for fire brigades; and for sky signs.

The **Infectious Diseases Prevention Act, 1890**, is another adoptive or optional Act; and any extra-metropolitan **S.A.** may by resolution adopt all or any of its sections, and may by further resolution rescind them. For London its leading provisions are contained in the Public Health (London) Act. The infectious diseases to which this Act applies are those specified in (or added to) the Infectious Diseases Notification Act. The principal provisions are as follows:—

Milk supplies.—If the **M.O.H.** has reason to believe that the consumption of milk from any dairy* (within or without his district) has caused or is likely to cause infectious disease to any person residing in the district, he may (if authorized by a Justice having jurisdiction in the place where the dairy is situate) inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by consumption of the milk, he must report to the **S.A.**, forwarding also any report furnished to him by the veterinary surgeon. The **S.A.** may then give not less than 24 hours' notice to the dairyman to appear before them, and show cause why the supply of the milk in their district should not be prohibited. If, in their opinion, he fails to show such cause, they may order accordingly, and must give notice of the facts to the **S.A.** and the County Council of the district in which the dairy is situate, and to the **L.G.B.** The order must be forthwith withdrawn on the **S.A.** or the **M.O.H.** being satisfied that the milk supply has been changed, or that the cause of infection has been removed. Penalties are provided for contravention of this section of the Act.

Disinfection.—Where the **M.O.H.** or any registered medical practitioner certifies that the cleansing and disinfection of any house, or part thereof, and of any articles therein, would tend to prevent infection, the **S.A.** may, after 24 hours' notice to the owner or occupier, proceed to carry out such disinfection or cleansing, unless within that time he informs the **S.A.** that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the **M.O.H.** If he fail to do this within the specified period, it is to be done by the officers of the **S.A.**, under the superintendence of the **M.O.H.**, and the expenses may be recovered. Power of entry between 10 a.m. and 6 p.m. is given for the purposes of this section. Where the section is adopted, the 120th section of the Public Health Act, 1875, is repealed.

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* Including any farm, farmhouse, cowshed, milk store, milk-shop, or other place from which milk is supplied or in which it is kept for the purpose of sale.

The **S.A.** may, by written notice, require (under penalty) any infected clothing or other articles to be delivered to their officer for disinfection. The **S.A.** must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

Any person who shall cease to occupy any house or room in which any person has, within six weeks, been suffering from any infectious disease (*a*) must have such house or room (and all articles therein liable to retain infection) disinfected to the satisfaction of a registered medical practitioner, as testified by a certificate signed by him; (*b*) must give to the owner notice of the previous existence of such disease; and (*c*) must not knowingly make a false answer when questioned by the owner, or by any person negotiating for the hire of the house or room, as to there having, within six weeks previously, been therein any person suffering from any infectious disease. Penalties are provided in each case. The **S.A.** must give notice of the provisions of this section to the occupier of any house in which they are aware there is a person suffering from an infectious disease.

Prompt interment.—The body of a person who has died of any infectious disease must not, without a certificate from the **M.O.H.** or a registered medical practitioner, be retained for more than 48 hours elsewhere than in a mortuary, or in a room not used at the time as a dwelling-place, sleeping-place, or workroom. In such cases, and also where any corpse is retained in a building so as to endanger the health of the inmates, a Justice may, upon the application of the **M.O.H.**, order the body to be removed by the **S.A.** to a mortuary, and to be buried within a specified time. Unless the friends undertake to bury, and do bury within the specified time, the relieving officer must do so. The body of any person who has died from infectious disease in a hospital must not be removed except for immediate interment or to a mortuary, if the **M.O.H.** or a registered practitioner certify that such restriction is desirable for preventing infection. The body of any person who has died from an infectious disease must not be conveyed in any public conveyance (other than a hearse) without due warning to the owner or driver, who must forthwith provide for disinfection.

Detention in hospital.—Any person suffering from any infectious disease, and being an inmate of a hospital for infectious diseases, and who upon leaving would be without accommodation in which due precautions could be taken against the spread of infection, may, by order of a Justice, be detained in hospital (at the cost of the **S.A.**) for any specified period, and such period may be extended as often as necessary.

The **S.A.** shall provide free temporary shelter, with any necessary attendance, for the members of any family in which infectious disease has appeared, who have to leave their dwelling to allow of disinfection by the **S.A.**

Infectious rubbish must not be thrown into any receptacle for refuse without previous disinfection. Notice of this prohibition must be served by the **S.A.** upon the master of any house in which there is any case of dangerous infectious disease.

The Midwives Act, 1902, provides for the training of midwives and the regulation of their practice. The Central Midwives Board (under the Privy Council) publishes an official Roll of midwives, holds examinations, issues and cancels certificates, regulates training, supervises practice, and publishes rules. The Roll consists of those who have passed the C.M.B. examination (now about 21,000) or have fulfilled certain prescribed conditions at the time of, or within two years after, the passing of the Act (another 19,000). Of the 40,000 midwives enrolled, about 12,000 are in practice. The Board may suspend or remove midwives from the Roll. Every County Council and County Borough Council is the "local Supervising Authority" over midwives in their area. In addition to the annual registration of midwives, the following duties are imposed upon the Authority by s. 8 :—

(*a*) To exercise general supervision over all midwives practising within their area, in accordance with the Rules laid down under the Act.

(*b*) To investigate charges of malpractice, negligence, or misconduct on the part of any midwife practising within their area, and, should a prima-facie case be established, to report the same to the Central Midwives Board.

(*c*) To suspend any midwife from practice, in accordance with the Rules under this Act, if such suspension appears necessary in order to prevent the spread of infection.

(*d*) To report offences, to correct addresses, and to notify deaths of midwives.

The local Supervising Authority may delegate, with or without conditions and restrictions, any of their powers or duties to a Committee appointed by them, consisting wholly or partly of members of the Authority (women being eligible). A County Council may likewise delegate to any District Council within their area (s. 9). Certified midwives must give notice of their intention to practise to the local Sanitary Authority or the body to whom their duties have been delegated. The Midwives (Scotland) Act, 1915, is modelled on the English Act, but provides in addition for reciprocal treatment of midwives certified in other parts of the British dominions, for facilities for suspension from practice, for certain financial payments, for powers of entry for inspection of lying-in homes, and for a more elastic organization of the Central Midwives Board for Scotland.

The **Rules of the Central Midwives Board, 1916,** regulate the proceedings of the Board, and the training, certification, and supervision of midwives. The course of training must extend over at least six months, and must include attendance at twenty labours and the nursing of twenty lying-in women and their infants for the ten days following labour; attendance at twenty lectures on elementary anatomy and physiology of female pelvis and organs, hygiene and diseases of pregnancy, the management of labour and the puerperium (mechanism, course, signs, and symptoms), obstetric emergencies, puerperal fever, venereal disease, antiseptics, disinfection, care of infancy, etc. The period of six months is reduced to four for hospital nurses of three years' training. Candidates for examination must be not under 21 years of age, of good character, and of sufficient general education. Midwives may be removed from the Roll for certain offences and for disobeying the Rules. Inquiry is made into their conduct by the Board and the local Supervising Authority; under specified conditions names may be restored to the Roll.

The regulations as to supervision include (*a*) directions to midwives concerning their personal health and cleanliness, care of instruments, and preparatory and instructional visitation of pregnant woman before delivery; (*b*) duties to the patient; (*c*) duties to the child; (*d*) conditions in which medical assistance must be obtained (in regard to complications of pregnancy, labour, lying-in, and the care of the child); and (*e*) the necessary notification to the local Supervising Authority when medical advice has been needed, when the death of mother or child (including stillbirth) has occurred in the absence of the practitioner, when the midwife has prepared a dead body for burial, or when there is a liability to puerperal or other infection (after the occurrence of which there must be effective disinfection of person, clothing, and instruments), The local Supervising Authority must secure proper inspection of every midwife's case-book, bag of appliances, and, where necessary, her residence and mode of practice. Under the Notification of Births Acts, 1907 and 1915, it is the duty of the midwife to notify the birth of the child to the Medical Officer of Health within thirty-six hours of its occurrence; under the Public Health (Ophthalmia Neonatorum) Regulations, 1914, to notify similarly any case of ophthalmia neonatorum, if not notified by the medical practitioner; and under the Infectious Diseases Notification Acts, 1889 and 1899, to notify the occurrence of puerperal or other fevers.

The necessity for skilled midwifery is obvious in view of maternal and infant mortality and disease. In 1915 the deaths assigned to pregnancy or childbirth numbered 3,408, one-third being due to puerperal fever. In addition there were 881 deaths of women at childbirth due to associated conditions. Many deaths of infants occur in relation to childbirth (including some stillbirths and deaths within a few days or hours of birth). Authorities hold that reform is necessary in regard (*a*) to improved training, status, and remuneration of midwives; (*b*) to an increase in their number and a reduction in the number of cases taken per midwife; (*c*) to the inspection and control of midwives, and of training institutions, by competent midwives; (*d*) to the closer association of midwives with health visitors and maternity centres; (*e*) to an improved co-ordination between prenatal, natal, and postnatal agencies of treatment.

Local Government Act, 1888.—The sanitary provisions of this important Act are few. Besides the powers in respect of pollution of streams conferred upon County Councils by s. 14, and the provisions as to the appointment and qualifications of county and other **M.O.H.** contained in ss. 17 and 18 (*see* Chap. XVII.), only the following require mention here:—

> A County Council may, subject to the approval of the **L.G.B.**, make bye-laws in relation to the whole or any specified part of their county (boroughs excepted)* for various purposes, including the prevention and suppression of nuisances not already punishable in a summary manner by virtue of any Act in force throughout the county (s. 16).
>
> Every **M.O.H.** for a district in any county shall send to the County Council a copy of every periodical

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* Boroughs have the same power under s. 23 of the Municipal Corporations Act, 1882.

report * of which a copy is, for the time being, required by the Regulations of the **L.G.B.** to be sent to the Board; and if the **M.O.H.** fail to send such copy, the County Council may refuse to pay any contribution towards his salary. If it appear to the County Council from any such report that the Public Health Act, 1875, has not been properly put in force within the district to which the report relates, or that any other matter affecting the public health of the district requires to be remedied, the Council may cause a representation to be made to the **L.G.B.** on the matter (s. 19).

County Councils have now certain powers under the Housing of the Working Classes Act, and they have, of course, power to make formal or informal representations to the **L.G.B.**, or other controlling Authority, upon any matter.

The **Local Government Act, 1894,** does not apply to county boroughs, nor to London, Scotland, or Ireland.

Area and boundaries.—Boundaries are to be adjusted so as to prevent intersection of those which define counties, county districts, unions, and parishes. Small rural parishes are to be grouped into workable units for parish council purposes, but each is to have its parish meeting. In rural districts *Parish Meetings* and *Parish Councils* are constituted.

The **Parish Meeting** has the exclusive power of adopting certain optional Acts, including the Burials Acts and the Baths and Washhouses Act, and its consent is required before the Parish Council can incur any expense involving a loan or a rate exceeding 3d. in any year.

The **Parish Council** have power (s. 8) "to utilize any well, spring, or stream within their parish and provide facilities for obtaining water therefrom,† but so as not to interfere with the rights of any corporation or person; and to deal with any pond, pool, open ditch, drain, or place containing or used for the collection of any drainage, filth, stagnant water, or matter likely to be prejudicial to health, by draining, cleansing, covering it, or otherwise preventing it from being prejudicial to health, but so as not to interfere with any private right or the sewage or drainage works of any local Authority." They may execute works for these purposes, or contribute to the cost. They may complain (s. 16) to the County Council if the Rural District Council have failed to provide or to maintain sufficient drainage or water supply for the parish, or to enforce any provision of the Public Health Act, and in that event the County Council may take over to themselves the powers of the District Council for the purpose, or may make an Order for the necessary works to be carried out by the District Council or by some person appointed by the County Council. Notice must be given to the Parish Council concerned if the Rural District Council decide to undertake works of sewerage or water supply. The Parish Council may acquire or hire land for allotments, and may, if necessary, appeal to the County Council for compulsory powers of purchase or hire; the Order, if granted, requires confirmation by the **L.G.B.** (ss. 9 and 10). They may also make official representations to the District Council under the Allotments Acts; or to the **M.O.H.** as to unhealthy dwellings or obstructive buildings under the Housing of the Working Classes Act (*see* p. 659 *et seq.*); or to the **L.G.B.** with a view to the grant of urban powers for their parish or any part of it. The District Council may delegate to them any powers which under the Public Health Acts could be delegated to a parochial committee. Apart from expenditure under adoptive Acts, the Parish Council must not incur expenses involving more than a 6d. rate in any year, nor more than a 3d. rate without the consent of the Parish Meeting. They may raise money on loan, but only with the approval of the Parish Meeting, the County Council, and the **L.G.B.**

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* The Regulations of the L.G.B. require the M.O.H. to furnish the County Council with copies of special as well as annual reports. (*See* pp. 569–70.)

† They cannot, except by agreement, acquire land for the purpose of any supply of water (s. 9).

Rural District Councils, notwithstanding the limited initiative possessed by the Parish Council, are the responsible executive Sanitary Authority, and must carry out all necessary works, giving notice to the Parish Council. The **L.G.B.** may by General Order confer upon Rural District Councils such urban powers as they think fit; this is in addition to their right under the Public Health Act of 1875 (*see* p. 586) to grant urban powers for particular areas, which right may under the 1894 Act be exercised by the Board on the application of the County or Parish Council concerned.

Urban District Councils are the **S.A.** for urban districts. Boroughs have their "Corporation" or "Town Council," but are included in the term "county district," which comprises all urban and rural districts.

All District Councils have the charge of highways. Among other powers given to them are the administration of the Acts relating to petroleum and infant life protection, and the licensing of knackers' yards. A District or Parish Council may delegate their powers to a committee of their number, or to a joint committee representing other Councils also.

County Councils obtain under the 1894 Act certain powers of supervision and control, specified in the foregoing summary.

Sale of Food and Drugs Act, 1875.—This Act defines "food" as including every article used by man for food or drink, except water and drugs; and "drugs" as including medicine for external as well as internal use (s. 2). "No person shall mix, colour, stain, or powder (or order or permit any other person to mix, colour, stain, or powder) any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state; and no person shall sell any article so mixed, coloured, stained, or powdered . . . " (s. 3). "No person shall, except for the purpose of compounding, ... mix, colour, stain, or powder (or permit any other person to mix, colour, stain, or powder) any drug with any ingredient or material so as to affect injuriously the quality or potency of such drug, with intent that the same may be sold in that state; and no person shall sell any drug so mixed, coloured, stained, or powdered . . ." (s. 4). The penalty for such injurious admixture is a fine not exceeding £50 for a first offence; subsequent offences are misdemeanours, punishable by imprisonment with hard labour for a period not exceeding six months. No liability is, however, incurred if the accused person can show that he was unaware of the admixture, and could not, with reasonable diligence, have ascertained it (s. 5).

"No person shall sell, to the prejudice of the purchaser, any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser, under a penalty not exceeding £20; but no offence shall be deemed to be committed under this section in the following cases: (1) Where any matter or ingredient not injurious to health has been added to the food or drug because the same is required for the production or preparation thereof as an article of commerce in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight, or measure of the food or drug, or conceal the inferior quality thereof; (2) where the drug or food is a proprietary medicine, or is the subject of a patent in force, and is supplied in the state required by the specification of the patent; (3) where the food or drug is compounded . . . . [and the provisions of the seventh and eighth sections are observed]; (4) where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation" (s. 6). As regards these exemptions, the *onus probandi* rests with the defendant (s. 24). No person shall sell any compound, drug, or article of food which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding £20 (s. 7); but no offence under this section is committed in respect of the sale of a drug or article of food mixed with an ingredient not injurious to health, if it is labelled as "mixed" at the time of sale (s. 8).

"No person shall (with the intent that the same may be sold in its altered state without notice) abstract from an article of food any part of it, so as to affect injuriously its quality, substance, or nature; and no person shall sell any article so altered without making disclosure of the alteration, under a penalty not exceeding £20" (s. 9). In any prosecution under this Act, the defendant is to be discharged if he proves to the satisfaction of the Court (*a*) that he bought the article as being the same in nature, substance, and quality with that demanded by the purchaser, and with a written warranty to that effect; (*b*) that at the time of sale he had no reason to believe it to be otherwise; and (*c*) that he sold it in the same state as when he purchased it (s. 25).

In every district a competent person may be (and, if required by the **L.G.B.**, must be) appointed as Public Analyst* (s. 10); and any person shall be entitled to have any drug or article of food purchased by him in such district analysed by the Public Analyst on payment of a sum not exceeding 10s 6d., and to receive from him a certificate of the result of the analysis (s. 12). The **M.O.H.**, inspector, or constable, charged by the **S.A.** with the execution of the Act, may procure samples of food and drugs, and submit them to the Public Analyst (s. 13). Any person purchasing an article for analysis shall, upon the completion of the purchase, forthwith notify to the seller his intention to have it analysed by the Public Analyst; and shall offer to divide it into three parts, to be then and there separated, and each part to be marked and sealed or fastened up, and shall, if required to do so, proceed accordingly, and shall deliver one of the parts to the seller. He shall retain one of the three parts for future comparison, and deliver the third to the Public Analyst (s. 14). If the seller do not accept the offer of division, the analyst must divide the article into two parts, and seal up and deliver one of them to the purchaser (s. 15). Samples may be sent to the analyst by registered parcel post, if his residence is two miles from that of the purchaser (s. 16). Any person refusing to sell to an officer of the **S.A.** any article of food or drug on sale by retail, the price being tendered, and the quantity demanded not being greater than is reasonably requisite, is liable to a penalty not exceeding £10 (s. 17). The certificate of the analyst must be in a prescribed form (s. 18), and is sufficient evidence of the facts therein stated, unless the defendant requires the analyst to be called as a witness (s. 21). The Justices before whom a case is heard may, at the request of either party, cause any article of food or drug to be sent to the Commissioners of Inland Revenue for analysis at the Government Laboratory (s. 22).

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* The appointment is made by the Town Council of any borough having a separate Court of Quarter Sessions, or a separate Police establishment. The County Council appoints the Public Analyst for all parts of the county not included in the above. All appointments and reappointments are subject to the approval of the L.G.B.

Sale of Food and Drugs Act Amendment

Act, 1879.—This amending Act was passed in order to settle certain points upon which the 1875 Act was found to be insufficiently explicit.

"It shall be no defence to allege that the purchaser is not prejudiced by the sale of adulterated articles, on the ground that he bought it for analysis only; or to allege that the article in question, though defective in nature, *or* substance, *or* quality, was not defective in all three respects" (s. 2). "The **M.O.H.**, inspector, or constable charged with the execution of the Act, may procure, at the place of delivery, a sample of milk in course of delivery to the purchaser or consignee, in pursuance of any contract; and may submit the sample to the Public Analyst" (s. 3). "The seller, or his representative, if he refuses to allow a sufficient sample to be taken, is liable to a penalty not exceeding £10" (s. 4). "As regards spirits not adulterated otherwise than by admixture of water, it is a good defence to prove that the admixture has not reduced the spirit more than 25 degrees under proof for brandy, whisky, or rum; or 35 degrees under proof for gin" (s. 6).

The **Sale of Food and Drugs Act, 1899**, provides that articles imported into the United Kingdom, such as margarine, margarine cheese, impoverished or adulterated milk, condensed, separated, or skimmed milk, or any other article hereafter added by Order in Council, shall be conspicuously marked with name and description (s. 1); the **L.G.B.** and the Board of Agriculture may procure samples for analysis if it is deemed desirable in the general interest of the consumer, and the results of the analysis shall be communicated to the **S.A.**, who shall pay the analyst's fees (s. 2). Under s. 3 similar power is given to these Boards to act in default of the **S.A.** The Board of Agriculture may make regulations for determining what deficiency in any normal constituents, or adulterations, shall raise a presumption that milk, cream, butter, and cheese is not genuine (s. 4). The Margarine Act, 1887, is extended to apply to "margarine cheese," which must be clearly marked on the package in black letters not less than ½ in. long. Every maker of margarine and margarine cheese shall keep a register as to quantity and destination of his consignments, and he shall submit to inspection (s. 7). The fat of margarine must not contain more than 10 per cent. of butter fat (s. 8), and condensed milk of all kinds may only be sold when clearly described on the label. A person selling milk on any highway must have conspicuously marked on the vehicle his name and address.

Penalties for wilful obstruction of officers in the course of their duties in food sampling and for offences under the Acts, are, for the first offence, sums not exceeding £20, and for subsequent offences £50 and £100; but proceedings may not be instituted after the expiration of 28 days from the time of purchase. A warranty is not available as a defence unless a copy has been sent to the purchaser within seven days of service of the summons, with a written notice stating that reliance will be placed on it, and specifying the name and address of the warrantor.

These Acts are directed not only against fraudulent dilution, abstraction, and substitution, but also against injury to health, and the sampling and analysis should be guided by consideration of both points. In the case of beer the risk of lead contamination from pewter pipes has long been known, but that of arsenic was overlooked until 1900.

The **Margarine Act, 1887**, defines "butter" as made exclusively from milk, or cream, or both, with or without salt or other preservative, or added colouring matter. "Margarine" includes all substances, whether compounds or otherwise, prepared in imitation of butter, whether mixed with butter or not (s. 3).

Every package of margarine must be so marked, in capital letters not less than ¾ in. square, and in shops by labels with capital letters not less than 1½ in. square. All margarine factories must be registered with the Authority appointing the Public Analyst of the district (s. 9). Officers authorized under the Sale of Food and Drugs Acts may take samples of butter (or substances purporting to be butter which are exposed for sale and not marked as margarine) without going through the form of purchase required by that Act, but otherwise complying with its provisions as to dealing with the samples (s. 10). Any such substance not being marked as margarine is to be presumed to be exposed for sale as butter. The vendor is absolved if he proves that he bought the article with a written warranty, and sold it, in the same state as when bought, believing it to be butter. The penalty for a first offence is a fine not exceeding £20.

The **Butter and Margarine Act, 1907,** substitutes for the definition of margarine in the Act above mentioned the following words: "Margarine shall mean any article of food, whether mixed with butter or not, which resembles butter and is not milk-blended butter." This Act also gives powers of inspection to the Board of Agriculture, the **L.G.B.,** and the **S.A.** over all processes of manufacture, blending, reworking, or treatment of butter and similar substances, and a limit is laid down by which not more than 16 per cent. of moisture is permitted in butter and margarine, and not more than 24 per cent. in milk-blended butter. Nor may such goods be imported. New powers are also given as to the proportion of milk solids in butter, as to the making of regulations by the **L.G.B.** for prohibiting the use of preservatives in butter, margarine, and milk-blended butter, and as to labelling these several articles.

Sale of Horseflesh, etc., Regulation Act, 1889.—The flesh of horses, asses, or mules must not be sold or kept for sale for human food, except in a shop or stall over or upon which is placed conspicuously, in legible characters 4 in. long, an announcement that horseflesh is sold there. If otherwise, the **M.O.H.** or inspector may seize the meat and carry it before a magistrate, who may order as to its disposal as he thinks fit; and the offendor is liable to penalty. These conditions apply to such flesh cooked or uncooked, and alone or mixed with other substances. It is illegal to supply horseflesh for human food to a purchaser asking for other meat, or for a compounded article not usually made of horseflesh.

The **Rivers Pollution Prevention Act, 1876,** deals separately with (*a*) solid matters, (*b*) sewage, (*c*) trade effluents, and (*d*) mining effluents.

(*a*) No solid refuse of any kind may be put into any stream, so as to interfere with its due flow or to pollute its waters (s. 2).*

(*b*) No solid, or liquid sewage matter may be passed into any stream; but as regards conditions in existence prior to 1876 no offence is committed under this Act if it is shown that the best practicable and available means are being used to render harmless the sewage entering the stream (s. 3).

(*c*) No poisonous, noxious, or polluting liquid from any factory or manufacturing process may be passed into any stream. The saving clause as to conditions existent prior to 1876 is repeated here (s. 4).

(*d*) No solid matter from mines may be put into any stream so as prejudicially to affect its flow; nor may any poisonous, noxious, or polluting solid or liquid matter from mines be passed into any stream, other than water in the same condition in which it has been raised or drained from such mine (s. 5).

Proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or **S.A.** aggrieved (s. 8); but in respect of manufacturing or mining effluents **S.A.s** only can take action, and subject to the approval of the **L.G.B.** The Board, in giving or withholding consent, shall have regard to the industrial interests involved, and the circumstances and requirements of the locality. They shall not give their consent to proceedings by the **S.A.** of a district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the effluents from such manufacturing processes are reasonably practical and available, and that no material injury to the interests of such industry will be caused by the proceedings (s. 6). Any person interested may call the attention of the **S.A.** to pollution by manufacturing or mining effluents, and, if the **S.A.** refuse to move, may appeal to the **L.G.B.**, and the Board may, after due inquiry, direct the Authority to take proceedings (s. 6).

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* *See also* **Public Health Acts Amendment Act, 1890 (p. 605).**

The **S.A.** must afford facilities for admitting trade effluents into sewers, unless they would prejudicially affect the sewers or interfere with the disposal of the sewage, or be injurious in a sanitary point of view, from their temperature or otherwise; or unless the sewers are only large enough for the ordinary requirements of the district (s. 7).

[S. 14 of the Local Government Act, 1888, confers upon County Councils the powers of **S.A.s** under the Rivers Pollution Prevention Act; and enables the **L.G.B.** to form a joint committee representing all administrative counties through or by which a river, or any specified portion of a river, or any tributary thereof, passes, and to confer upon the joint committee all or any of the powers of a **S.A.** under the Act.]

The Royal Commission on Sewage Disposal recommended in 1903 the formation of River Boards throughout the country, composed of joint committees of County Councils, for the purpose of properly enforcing the R.P.P. Act. Such Boards have the advantage of jurisdiction over the whole of a drainage area and are sufficiently large to secure the appointment of skilled officers. Some have extended powers under special Acts.

A short explanatory Act (R.P.P. Act, 1893) removes a technical difficulty liable to be raised by **S.A.s** seeking to evade their responsibilities under s. 3.

Canal Boats Act, 1877.—The term "canal" includes all navigable waters, tidal or otherwise, within the body of a county, and the term "canal boat" includes every vessel, however propelled, used for conveyance of goods along such waters, but does not include a ship registered under the Merchant Shipping Act, unless the **L.G.B.** orders otherwise. No canal boat may be occupied as a dwelling unless it is registered under this Act, and then only by the number of persons of the age and sex for which it is registered "(s. 1). The registration authority must be a **S.A.** whose district abuts on the canal on which the boat is intended to ply; and the boat must be registered as belonging to some place which is within the said district, and which is also within a school district (s. 7). Upon registration two certificates must be given to the owner, identifying the owner and the boat, and stating the place to which it belongs, and the number, age, and sex of persons allowed to dwell in the boat. The master of the boat must carry one of these certificates. Every registered boat must have conspicuously painted upon it the registered number, the place to which it belongs, and the word "registered" (s. 3). If any person on a canal boat is suffering from an infectious disease, the **S.A.** of the place where the boat is shall adopt such precautions as appear necessary, upon the certificate of the **M.O.H.** or other legally qualified practitioner; and may remove such sick person and exercise the other powers conferred by the Public Health Act in this respect; and may detain the boat as long as is necessary for cleansing and disinfecting (s. 4). If any person duly authorized by the **S.A.** has reason to suspect any contravention of the Act, or that a person on board is suffering from an infectious disease, he may enter the boat for the purpose of inspection between 6 a.m. and 9 p.m., and may require the master of the boat to afford him facilities for so doing, and to produce the certificate of registry of the boat (s. 5).

The second section directs the **L.G.B.** to make regulations (i.) for the registration of canal boats; (ii.) for lettering, marking, and numbering such boats; (iii.) for fixing the number, age, and sex of persons who may be allowed to dwell in a canal boat, having regard to the cubic space, ventilation, separation of the sexes, general healthiness, and convenience of accommodation; (iv.) for promoting cleanliness and habitable condition of such boats; and (v.) for preventing the spread of infectious disease by canal boats.

Such regulations were accordingly issued by the **L.G.B.** in 1878, and the following is a summary of their principal sanitary provisions:—

> There must be at least one dry, clean, weatherproof cabin, in good repair. An after-cabin intended to be used as a dwelling must contain not less than 180 cub. ft. of free air space, and a fore-cabin 80 cub. ft.; every such cabin must have means of ventilation besides the door, and must be so constructed as to provide adequate sleeping accommodation. One cabin must contain a stove and chimney. The boat must be furnished with suitable storage for three gallons of water. If intended to be ordinarily used for foul cargoes, the hold must be separated from any inhabited cabin by a double bulkhead with an interspace of 4 in., and the bulkhead next the cargo must be water-tight. Not less than 60 cub. ft. of air space must be allowed for each person over 12 years of age, and not less than 40 cub. ft. for each person under that age. In "fly-boats" that are worked by shifts, a cabin occupied at the same time by two persons must have a capacity of 180 cub. ft. A cabin in which a married couple sleep must not be occupied at the same

time by any other male above 14, or female above 12 years of age. Males above 14 and females above 12 years of age must not occupy the same sleeping cabin at the same time, but reservation is made for married couples, and also (under certain conditions) in respect of boats constructed prior to 1878. The interior of the cabin must be repainted every three years, and must be kept clean. Bilge water must be pumped out daily. The master of the boat must at once notify the occurrence of any case of infectious disease on the boat to the **S.A.** of the district through which the boat may be passing, and also to the **S.A.** of the place of destination; he must also inform the owner, who is required to notify the **S.A.** of the place to which the boat belongs. If the boat is detained by the **S.A.** for purposes of disinfection, the **S.A.** must obtain a medical certificate that the boat has been cleansed and disinfected, and must give it to the master.

The **Canal Boats Act, 1884,** amends the 1877 Act in certain details, and makes it incumbent upon every **S.A.** through whose districts any canal passes to enforce the provisions of the Act and Regulations, and to make an annual report upon the subject to the **L.G.B.**[*] The Board is required to make inquiries from time to time (by an inspector or inspectors specially appointed for the purpose) as to the working of the Acts and Regulations, and to report annually thereon to Parliament.

Milk and Dairies (Consolidation) Act 1915.—S. 1 provides that the **L.G.B.** may make general or special Milk and Dairies Orders as they think fit for all or any of the following purposes:—

(*a*) For the registration with local authorities of all persons carrying on the trade of dairymen, and of all dairies;

(*b*) for the inspection of cattle in dairies, and of dairies and persons in dairies who have access to the milk, the churns or other milk receptacles;

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[*] This report has to be drawn up in prescribed form and must include particulars as to registration, notification of change of master, certificate, marking of boat, overcrowding, separation of sexes, cleanliness, ventilation, painting, provision of water cask, removal of bilge water, notification of infectious disease, and admittance of inspector.

(*c*) for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water supply of dairies;

(*d*) for securing the cleanliness of milk stores, milk shops, and milk vessels used for containing milk for sale;

(*e*) for prescribing the precautions to be taken for protecting milk against infection or contamination;

(*f*) for preventing danger to health from the sale for human consumption, or from the use in the manufacture of products for human consumption, of infected, contaminated, or dirty milk;

(*g*) for regulating the cooling, conveyance, and distribution of milk intended for sale for human consumption, or its products;

(*h*) as to the labelling, marking, or identification and the sealing or closing of churns, vessels, and other receptacles of milk for sale for human consumption or used for the conveyance of such milk;

(*i*) for prohibiting the addition of colouring matter; and for prohibiting or regulating the addition of skimmed or separated milk or water or any other substance to milk intended for sale for human consumption, or the abstraction therefrom of butter-fat or any other constituent; and for prohibiting or regulating the sale for human consumption of milk to which such an addition or from which such abstraction has been made, or which has been otherwise artificially treated;

(*j*) for authorizing the use, in connexion with the sale of milk, of the designation "certified milk," for prescribing the conditions subject to which milk may be sold under such designation, and for prohibiting the use of such designation in connexion with the sale of milk in respect of which the prescribed conditions are not complied with;

(*k*) for authorizing a local Authority to make regulations for the purposes aforesaid, or any of them, subject to such conditions (if any) as the **L.G.B.** prescribe.

A Milk and Dairies Order may authorize the person making the inspection to require any cow to be milked in his presence and to take samples of the milk, and to require that the milk from any particular teat shall be kept separate and to take separate samples thereof.

S. 2 provides for powers of enforcing Milk and Dairies Orders.

S. 3 states that if the **M.O.H.** of a county or county borough is of opinion that tuberculosis is caused, or is likely to be caused, by the consumption of the milk supplied from any dairy in which cows are kept, he shall have power to stop the supply of milk from the dairy, subject to such right of appeal and the payment of compensation in such cases as are provided therein.

Under s. 4, if the **M.O.H.** has reason to suspect that tuberculosis is caused, or is likely to be caused, by the consumption of any milk which is being sold or exposed or kept for sale within the area of the local Authority, he shall endeavour to ascertain the source or sources of supply, and on ascertaining the facts shall forthwith give notice of them to the **M.O.H.** of the county or county borough in which the cows from which the milk is obtained are kept, in order that the cattle may be inspected by a veterinary surgeon, and veterinary, medical, and bacteriological reports furnished. Details of the administrative steps to be taken are set out in a schedule.

S. 5 prohibits the sale of milk from a cow which is tuberculous or suffering from mastitis, anthrax, actinomycosis, or foot-and-mouth disease.

The Act further provides for registration of all milk-sellers and -hawkers, and for the proper labelling of condensed, separated, or skimmed milk. It also amends the law with regard to sampling.

Other new powers and duties include the appointment of veterinary inspectors by the **S.A.**, the control of imported milk, and the establishment of infant milk depôts. The **L.G.B.** are empowered to act in default of the **S.A.** The Act is to come into force within one year of the termination of the War.

The **Dairies, Cowsheds, and Milkshops Order of 1885** was made by the Privy Council under s. 34 of the Contagious Diseases (Animals) Act of 1878. An amending Act (C.D.A. Act, 1886) transferred to the **L.G.B.** the powers of the Privy Council under this section, and the D.C. and M. Amending Order, 1886, substituted the Board for the Privy Council and remedied certain omissions in regard to penalties, giving the Order the force of law. The D.C. and M. Order of 1899 amended the previous Orders by including tuberculosis among the infective diseases on the occurrence of which milk should not be sold under s. 15. The effect of the three Orders (1885, 1886, 1899) is to throw upon every **S.A.** the duty of supervising the milk trade in their district, and of carrying out the regulations prescribed by the Orders. These duties are common to all districts alike, but any **S.A.** may arm itself with further powers by making Regulations under s. 13, having the force of bye-laws. The chief provisions of the Orders (which will in future come under the 1915 Act) are summarized below :—

Section 6. (1) It shall not be lawful for any person to carry on . . . the trade of cowkeeper, dairyman, or purveyor of milk unless he is registered as below. (2) Every **S.A.** shall keep a register of such persons, and shall from time to time revise and correct the register. (3) The **S.A.** shall register every such person, but registration shall not be deemed to authorize such person to occupy as a dairy or cowshed any particular building, or preclude proceedings. (4) The **S.A.** shall from time to time give public notice of registration being required, and of the mode of registration. (5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making and selling butter or cheese, or both, and who is not also a purveyor of milk, need not be registered. (6) A person who sells milk of his own cows in small quantities to his workmen or neighbours for their accommodation need not, by reason thereof, be registered.

Section 7. (1) It shall not be lawful to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order until provision is made, to the reasonable satisfaction of the **S.A.**, for the lighting and ventilation, including air-space, and the cleansing, drainage, and water-supply; or (2) without first giving one month's notice in writing to the **S.A.**

Section 8. It shall not be lawful to occupy as a dairy or cowshed any building—whether so occupied at the commencement of this Order or not—if . . . . the lighting and ventilation, including air-space, and the cleansing, drainage, and water supply thereof, are not such as are necessary or proper (*a*) for the health and good condition of the cattle therein; (*b*) for the cleanliness of milk-vessels used therein for containing milk for sale; and (*c*) for the protection of the milk therein against infection or contamination.

Section 9. It shall not be lawful for any . . . . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milkshop (*a*) to allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or to handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade . . . . so far as regards the production, distribution, or storage of milk; or (*b*) if himself so suffering, or having recently been in contact as aforesaid, to milk cows or handle vessels containing milk for sale, or in any way to take part in the conduct of his trade as far as regards the production, distribution, or storage of milk; until, in each case, all danger therefrom of the communication of infection to the milk or of its contamination has ceased.

Section 10. It shall not be lawful for any . . . . cowkeeper, dairyman, or purveyor of milk, or . . . . occupier of a milk-store or milkshop, after the receipt of notice of not less than one month from the local Authority calling attention to the provisions of this Article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or any room used as a milk store or milkshop.

Section 11. It shall not be lawful for any . . . . cowkeeper, or dairyman, or purveyor of milk, or occupier of a milk-store or milkshop, to use a milk-store or milkshop in his occupation, or permit the same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk-store or milkshop, and of the milk-vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12. It shall not be lawful for any . . . . cowkeeper, or dairyman, or purveyor of milk to keep any swine in any . . . . building used by him for keeping cows, or in any milk store or other place used by him for keeping milk for sale.

Section 13. Any **S.A.** may make regulations. (*a*) for the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilation,* cleansing, drainage, and water supply, of dairies and cowsheds . . . .; (*c*) for securing the cleanliness of milk-stores, milkshops, and milk-vessels used for containing milk for sale; and (*d*) for prescribing precautions to be taken by purveyors of milk, and persons selling milk by retail, against infection or contamination.

Section 14. The following provisions shall apply to regulations made by any **S.A.** under this Order: (1) Every regulation shall be published by advertisement in a newspaper circulating in the district. (2) The **S.A.** shall send to the **L.G.B.** a copy of every regulation at least a month before the date of operation. (3) The **L.G.B.** may at any time revoke any regulation if satisfied on inquiry that it is too restrictive or otherwise objectionable.

Section 15. The milk of a cow suffering from cattle-plague, pleuro-pneumonia, or foot-and-mouth disease (*a*) shall not be mixed with other milk; (*b*) shall not be sold or used for human food; and (*c*) shall not be sold or used for food of animals, unless it has been boiled. Tuberculosis is now included in this section under the D.C. and M.O. of 1899.

The following **Model Regulations** under s. 13 of the Order have been drawn up by the **L.G.B.** for Dairies, Cowsheds and Milkshops.

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* Where a minimum cubic space is specified for cowsheds in such Regulations, the **L.G.B.** have suggested 800 cub. ft. per head, but in many districts a lower standard has been adopted.

INTERPRETATION

1. The expression "cowshed" includes any dairy in which milking cows may be kept, and the expression "cowkeeper" means any person following the trade of a cowkeeper or dairyman required to be registered under the Order of 1885.

FOR THE INSPECTION OF CATTLE IN DAIRIES

2. Every occupier of a dairy wherein any cattle may be kept, and which the **M.O.H.**, or the Inspector of Nuisances, or any other officer of the Council specially authorized by them in that behalf, may visit for the purpose of inspecting cattle, and every person for the time being having the care or control of any such dairy, or of any cattle therein, shall afford such officer all reasonable assistance that may, for the purpose of the inspection, be required by him.

FOR PRESCRIBING AND REGULATING THE LIGHTING, VENTILATION, CLEANSING, DRAINAGE, AND WATER SUPPLY OF COWSHEDS AND DAIRIES

PART I

The Regulations in this Part shall apply to cowsheds the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day.

3. *Lighting.*—Every cowkeeper shall provide that every cowshed in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

4. *Ventilation.*—Every cowkeeper shall cause every cowshed in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the cowshed in a wholesome condition.

5. *Cleansing.*—(1) Every cowkeeper shall cause every part of the interior of every cowshed in his occupation to be thoroughly cleansed from time to time as often as may be so necessary to secure that such cowshed shall be at all times reasonably clean and sweet.

(2) Such person shall cause the ceiling or interior of the roof and walls of every cowshed in his occupation to be properly limewashed *twice* at least in every year, that is to say, *once* during the month of May and *once* during the month of October, and at such other times as may be necessary.

Provided that this requirement shall not apply to any part of such ceiling, roof, or walls that may be properly painted, or varnished, or constructed of or covered with any material such as to render the limewashing unsuitable or inexpedient, and that may be otherwise properly cleansed.

(3) He shall cause the floor of every such cowshed to be thoroughly swept, and all dung and other offensive matter to be removed from such cowshed as often as may be necessary, and not less than *once* in every day.

6. *Drainage.*—(1) Every cowkeeper shall cause the drainage of every cowshed in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to a drain inlet situate in the open air at proper distance from any door or window of such cowshed, or to some other suitable place of disposal which is so situate.

(2) He shall not cause or suffer any inlet to any drain of such cowshed to be within such cowshed.

7. *Water supply.*—(1) Every cowkeeper shall keep in, or in connexion with, every cowshed in his occupation a supply of water suitable and sufficient for all such purposes as may from time to time be reasonably necessary.

(2) He shall cause any receptacle which may be provided for such water to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein, and where such receptacle is used for the storage only of water he shall cause it to be properly covered and ventilated, and so placed as to be at all times readily accessible.

PART II

The Regulations in Part I., and also the following Regulation, shall apply to all cowsheds other than those the cows from which are habitually grazed on grass land during the greater part of the year, and when not so grazed are habitually turned out during a portion of each day.

8. A cowkeeper shall not cause or allow any cowshed in his occupation to be occupied by a larger number of cows than will leave not less than 800 cub. ft. of air-space for each cow.

Provided as follows:—

(*a*) In calculating the air-space for the purposes of this regulation, no space shall be reckoned which is more than 16 ft. above the floor; but if the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof for the purposes of this regulation.

(*b*) This Regulation shall not apply to any cowshed constructed and used before the date of these Regulations coming into effect until two years after that date.

PART III

9. In this Part the expression "dairy" means a dairy in which cattle are not kept.

10. *Lighting.*—Every cowkeeper shall provide that every dairy in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

11. *Ventilation.*—Every cowkeeper shall cause every dairy in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the dairy in a wholesome condition.

12. *Cleansing.*—(1) Every cowkeeper shall cause every part of the interior of every dairy in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such dairy shall be at all times reasonably clean and sweet.

(2) He shall cause the floor of every such dairy to be thoroughly cleansed with water at least *once* in every day.

13. *Drainage.*—(1) Every cowkeeper shall cause the drainage of every dairy in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable opening channel to the outside of such dairy, and may there be received in a suitable gully communicating with a proper and sufficient drain.

(2) He shall not cause or suffer any inlet to any drain of such dairy to be within such dairy.

14. *Water supply.*—(1) Every cowkeeper shall cause every dairy in his occupation to be provided with an adequate supply of good and wholesome water for the cleansing of such dairy and of any vessels that may be used therein for containing milk, and for all other reasonable and necessary purposes in connexion with the use thereof.

(2) He shall cause every cistern or other receptacle in which any such water may be stored to be properly covered and ventilated, and so placed as to be at all times readily accessible.

(3) He shall cause every such cistern or receptacle to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein.

FOR SECURING THE CLEANLINESS OF MILK-STORES, MILK-SHOPS, AND OF MILK-VESSELS

15. *Cleanliness of milk-stores and milkshops.*—Every occupier of a milk-store or milkshop shall cause every part of the interior of such milk-store or milkshop to be thoroughly

cleansed from time to time as often as may be necessary to maintain such milk-store or milkshop in a thorough state of cleanliness.

16. *Cleanliness of milk-vessels.* — (1) Every cowkeeper shall from time to time, as often as may be necessary, cause every milk-vessel that may be used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water, and shall otherwise take all proper precautions for the maintenance of such milk-vessel in a constant state of cleanliness.

(2) He shall, on every occasion when any such vessel shall have been used to contain milk, or shall have been returned to him after having been out of his possession, cause such vessel to be forthwith so cleansed.

FOR PRESCRIBING PRECAUTIONS AGAINST INFECTION OR CONTAMINATION OF MILK

17. (1) Every purveyor of milk or person selling milk by retail shall take all reasonable and proper precautions, in and in connexion with the storage and distribution of the milk, and otherwise, to prevent the exposure of the milk to any infection or contamination.

(2) He shall not deposit or keep any milk intended for sale—

(*a*) in any room or place where it would be liable to become infected or contaminated by impure air, or by any offensive, noxious, or deleterious gas or substance, or by any noxious or injurious emanation, exhalation, or effluvium; or

(*b*) in any room used as a kitchen or as a living-room; or

(*c*) in any room or building, or part of a building, communicating directly by door, window, or otherwise with any room used as a sleeping-room, or in which there may be any person suffering from any infectious or contagious disease, or which may have been used by any person suffering from any such disease and may not have been properly disinfected; or

(*d*) in any room or building or part of a building in which there may be any direct inlet to any drain.

(3) He shall not keep milk for sale, or cause or suffer any such milk to be placed, in any vessel, receptacle, or utensil which is not thoroughly clean.

(4) He shall cause every vessel, receptacle, or utensil used by him for containing milk for sale to be thoroughly cleansed

with steam or clean boiling water after it shall have been used, and to be maintained in a constant state of cleanliness.

(5) He shall not cause or suffer any cow belonging to him or under his care or control to be milked for the purpose of obtaining milk for sale—

(*a*) unless, at the time of milking, the udder and teats of such cow are thoroughly clean; and

(*b*) unless the hands of the person milking such cow, also, are thoroughly clean and free from all infection and contamination.

PENALTIES

18. Every person who shall offend against any of the foregoing Regulations shall be liable for every such offence to a penalty not exceeding £5, and in the case of a continuing offence to a further penalty not exceeding 40s. for each day after written notice of the offence from the Council.

Provided, nevertheless, that the Justices or Court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this Regulation.

The **Public Health (London) Act, 1891,** forms a sanitary code for London, and includes (with many important additions and amendments) the main provisions of the Public Health Acts and the Infectious Diseases Notification and Prevention Acts. A brief summary of the principal points of divergence from the Acts named above is appended.

Water supply.—Absence of proper water supply, or of proper fittings, is held to render a house unfit for habitation. A new house must not be occupied until the **S.A.** grant a certificate that it has a proper water supply. A water company cutting off the supply of any house must give immediate notice to the **S.A.** For closure of polluted wells, etc., the **S.A.** have only to satisfy the Court that the water is "so polluted, or likely to be so polluted, as to be injurious or dangerous to health."

Closets.—A new house must have "one or more water-closets, as circumstances may require," with proper water supply and trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the **S.A.** Substitution of privies or earth-closets is only permissible if the available sewerage or water supply is insufficient for a water-closet. Penalties are prescribed for (*a*) wilfully injuring any drain or closet or water supply in connexion therewith; (*b*) discontinuing any such water supply without lawful authority; and (*c*) so constructing or repairing a water-closet or drain that it is a nuisance or injurious to health.

Scavenging.—The **S.A.** must cleanse streets, footpaths, cesspits, earth-closets, privies, and cesspools. They must remove house-refuse at proper intervals; and trade refuse also, if required to do so, on payment. They may undertake the collection of manure and other refuse, on request; or may, by order, require periodical removal by the owner.

Cellar dwellings.—No underground room not let or occupied separately as a dwelling before January 1st, 1892, can be so let or occupied, unless—

(*a*) every part is 7 ft. high, and at least 3 ft. above the level of the adjoining ground; but if the outside area is 6 ft. wide, or if its width is not less than the depth of the floor below ground-level, then only 1 ft. of the height need be above the ground-level;

(*b*) every wall has a damp-course, and, if in contact with the soil, is effectually secured from damp from the soil;

(*c*) there is an open area outside along the whole frontage, 4 ft. wide in every part, and 6 in. below the floor-level; it may be crossed by steps, but not opposite a window;

(*d*) the area and the soil immediately below the room are effectually drained;

(*e*) the hollow space (if any) below the floor is ventilated to the outer air;

(*f*) any drain under the room is made of gas-tight pipe;

(*g*) the room is effectually secured against the rising of any effluvium or exhalation;

(*h*) there is proper water-closet and ashpit accommodation;

(*i*) there is effectual ventilation;

(*j*) there is a fire-place, with chimney;

(*k*) there are one or more windows opening directly into the open air; the window-area being at least one-tenth of the floor area, at least half made to open, and in each case opening to the top.

The same conditions apply to underground rooms occupied separately as dwellings before January 1st, 1892; but the **S.A.**, either by general regulations or upon special application by the owner, may modify any conditions newly imposed by this Act which involve structural alteration of the building.

Keeping of animals.—Swine must not be kept within 40 yards of a street or public place, nor be allowed to stray in any public place. A Court may prohibit the keeping of any animal in any specified place shown to be unfit for the purpose.

Offensive trades.—None of the following must be established anew in London: Blood-boiling, bone-boiling, manure manufacture, soap-boiling, tallow-melting, or knacker's yard. Nor any of the following, without the sanction of the County Council: Fell-monger, tripe-boiling, slaughtering of cattle or horses, or other business which the County Council may, with the approval of the **L.G.B.**, add to the list. Slaughter-houses and knackers' yards must obtain licences, issued by the County Council, lasting for one year only, but renewable at the discretion of the County Council. The same applies to cowsheds.

Notification is compulsory. The medical certificate must state the patient's full name, postal address, age, sex, whether attended in public or private practice; if in hospital, the date of admission, and the place from which brought. The **M.O.H.** must, within twelve hours of receipt, send a copy of the certificate to the Metropolitan Asylums Board, and another to the head-teacher of the schools attended by the patient or by other inmates of the house. The Asylums Board must furnish to the County Council, and to every **M.O.H.**, such weekly returns of certificates so received by them as the County Council may prescribe. Any **S.A.** may, with the consent of the **L.G.B.**, add other dangerous infectious diseases to the list, temporarily or permanently, and the County Council have like power for the county as a whole.

Isolation.—A person who knows himself to be suffering from a dangerous infectious disease must not milk any animal, or pick fruit, or engage in any business in such manner as to be likely to spread the disease. He must not enter any public conveyance, nor must any other person place him, or convey him, in such.

Disinfection.—Every **S.A.** must provide disinfecting apparatus.

Mortuaries.—Every **S.A.** must provide a mortuary; the addition of a room for post-mortems is optional, unless ordered by the County Council. The County Council may provide other mortuaries wherein bodies may be kept for identification, and must provide proper accommodation for inquests.

Appointment of M.O.H. must not be for a limited period only. It is not terminable by the **S.A.** without the consent of the **L.G.B.** The **M.O.H.** must live in his district, or within a mile of the boundary. He must be qualified as stated on p. 546.

Sanitary Inspectors appointed after January 1st, 1895 (if they have not held office as sanitary inspector during three consecutive years prior to that date in a

London district or in an urban district outside London with a population of not less than 20,000), must hold a certificate of competence granted after examination by such body as the **L.G.B.** may from time to time approve.*

Default of S.A.—In the event of default of the **S.A.** with respect to the removal of any nuisance, the institution of any proceedings, or the enforcement of any bye-law, the County Council may act in their stead, and recover the expenses from the **S.A.** If the **L.G.B.** are satisfied, upon complaint from the County Council and after due inquiry, that the **S.A.** have made default in carrying out any part of this Act, they may order the **S.A.** to perform the duty within a specified time; and if this is not done, the order may be enforced by mandamus, or the **L.G.B.** may appoint the County Council to perform such duty, at the cost of the **S.A.**

Bye-laws.—The London County Council *must* make bye-laws—

(1) As to the time and manner of conveying offensive matters by road or water.

(2) As to the closure and filling up of cesspools and privies, removal and disposal of refuse, and duties of householders in facilitating removal of house refuse.

(3) As to water-closets, earth-closets, ashpits, cesspools, and receptacles for dung, and the proper accessories thereof in connexion with new or old buildings.

They *may* also make bye-laws as to the conduct of certain offensive trades, the buildings in which they are carried on, and the mode of application for sanction. These trades are fellmonger, tripe-boiler, slaughterer of cattle or horses; but other businesses may be afterwards added to the list.

Every London **S.A.** *must* make and enforce bye-laws relating to nuisances and keeping of animals, houses let in lodgings, and also the following:—

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* Such examinations are now conducted and certificates issued by the Sanitary Inspectors' Examination Board.

(1) For the prevention of nuisances arising from offensive matter running out of any manufactory, brewery, slaughter-house, knacker's yard, butcher's or fishmonger's shop, or dunghill, into any uncovered place, whether enclosed or not.

(2) For the paving of yards and open spaces in connexion with dwellings.

(3) For securing cleanliness, and freedom from pollution, of tanks, cisterns, and other receptacles of drinking-water.

(4) For maintaining the efficiency of flush for water-closets.

The **S.A.** *may* also make bye-laws relating to ship-borne infectious cases, public conveniences, mortuaries, and inhabited tents and vans.

The **London Building Act, 1894,** is a consolidation Act amending various enactments relating to streets and buildings in the metropolis. The Act is divided into an introduction and fifteen Parts, dealing with the formation and widening of streets, lines of building frontage, naming and numbering of streets, heights and construction of buildings, temporary, dangerous and neglected structures, sky-signs, and a number of similar miscellaneous matters. Some duties under the Act, such, for instance, as respect wooden structures, and in relation to the removal of obstructions in streets, are to be exercised by the Borough Councils; otherwise the Act is administered by the London County Council.

An Amending Act was passed in 1898 dealing with building extensions, fore-courts, the height of working-class dwellings, etc.

The **Cleansing of Persons Act, 1897,** gives power to **S.A.** to provide cleansing facilities free of charge (not to be considered as parochial relief or charity) to persons infested with vermin. In practice such cleansing includes a bath and disinfection of clothes.

The **Public Health (Regulations as to Food) Act, 1907**, amends the Public Health Act of 1896 by giving power to the **L.G.B.** to make regulations authorizing measures to be taken for the prevention of danger arising to public health from the importation, preparation, storage, and distribution of food or drink (other than drugs or water) intended for sale for human consumption. The Act applies the methods of control which, in pursuance of an earlier series of enactments, have long been in successful operation with respect to infectious disease. These enactments include s. 130 of the Public Health Act, 1875, as amended by the Public Health Act, 1896, and as extended to London by Section 113 of the Public Health (London) Act, 1891. The **L.G.B.** have made two sets of Regulations under the Act, one called "The Public Health (First Series: Unsound Food) Regulations, 1908," and the other "The Public Health (Foreign Meat) Regulations, 1908."

(*a*) The **Public Health (First Series: Unsound Food) Regulations, 1908,** have been framed with the object of securing that articles of food which are unsound, unwholesome, or unfit for human consumption, and which, as part of the cargo of a ship, are brought to a place in this country either as a place of destination or of deposit for transmission to a place of destination elsewhere in the United Kingdom, shall be dealt with at the port of discharge. Powers of inspection are conferred upon the **M.O.H.**, or any duly qualified medical practitioner or other person appointed or employed by the **S.A.** to act in the execution of the Regulations. Notices or certificates in writing should only be given by the **M.O.H.** or his assistant.

The **M.O.H.** is authorized to examine articles of food which have been landed within the district of the **S.A.**, or before they have been landed, necessary facilities being given for the purposes of his examination in the matter of convenient arrangement, unpacking, and the like, and for a warrant to enter premises in special cases. It will be his object not only to examine under the conditions which are most favourable to efficient inspection, but, in the case of perishable articles and foodstuffs in course of transit, so to conduct the examination as to avoid any needless detention of goods or unnecessary inconvenience to the traders concerned. For special examination (e.g. in the laboratory), powers of sampling are conferred. The Board consider it important that samples of foodstuffs, which themselves possess a material money value, should be taken only in cases where there is substantial reason for this course, and would recommend that a record should be kept of the nature and method of disposal of any such samples. Vouchers in respect of special samples thus taken should be supplied in all cases on the request of the owner or other person having charge of the goods. In certain circumstances the examination of an article of food by an officer of the **S.A.** shall not be made without the consent of the Officer of Customs. The Officer of Customs is, however, required to afford facilities for such examination, and the **M.O.H.** should confer from time to time, as circumstances require, with the Collector or other Chief Officer of Customs acting in his district, so as to secure co-operation between the officers concerned.

Under Article IV. the **M.O.H.** is empowered, himself or by an assistant, to seize and carry away an article of food which, in his opinion, is unsound or unwholesome, or unfit for human consumption, in order that application may be made to a Justice for an order of condemnation. Alternatively, the **M.O.H.**, by notice to the importer or to any other person having charge of the article, may require that until it has been examined by a Justice it shall not be removed from the place specified in the notice without permission. The Justice, if satisfied as regards the unsoundness of the particular food concerned, is required to condemn the food and order its destruction or its disposal under the supervision of the **M.O.H.** by such means and in such a manner as to prevent its being used for human consumption. If, however, evidence satisfactory to the Justice is adduced that the food in question, although unsound, is not intended for sale for human consumption, he is required to make an order dismissing the complaint. In the case of any articles which the **M.O.H.** has seized and carried away, it is desirable that he should afford all facilities which the circumstances may permit to the importer who wishes to make his own examination of the foods in question. The **S.A.** must keep for a period of not less than twelve months a record of any article of food destroyed or disposed of in pursuance of the Regulations. An abstract of these records should be furnished by the M.O.H. in his annual report, together with an account of proceedings which have been taken by him under the Regulations.

(*b*) The **Public Health (Foreign Meat) Regulations, 1908,** are designed to deal with foreign boneless meat which is imported in the form of scraps, trimmings, or other pieces not sufficiently identifiable with definite parts of a carcass, and which has not before importation been made ready for human consumption in the form of a sausage, or of another prepared or manufactured article of food; with imported tripe, tongues, or kidneys to which certain chemical preservatives have been applied; and with severed parts of a pig not prepared before importation as bacon or ham, and not contained in a package with an "official certificate" unopened on it or attached to it. These meats are classed together in the Regulations as "Foreign Meat of Class i.," and unless the importer of meat of this class exports it at his own expense, or furnishes proofs, in the manner prescribed by the Regulations, that it is not intended for sale for human consumption, the meat is required to be destroyed.

With a view to stopping the importation of carcasses of pigs from which the lymphatic glands about the throat and elsewhere are absent (thereby preventing the detection of evidence of tuberculosis and other disease in the carcass), the Regulations provide that carcasses of pigs, not prepared as bacon or ham, which are imported without the lymphatic glands, and from which the head has been removed (Foreign Meat of Class ii.), shall be dealt with in a similar manner to Foreign Meat of Class i.

Foreign Meat of Class iii. consists of the severed parts of a pig, not prepared as bacon or ham, and not being Foreign Meat of Class i., but contained in a package with an "official certificate" attached as evidence that the pig from which the meat is derived has been certified by a competent authority in the place of origin to be free from disease at the time of slaughter, and that the meat has been certified by the like authority to have been dressed or prepared, and packed with the needful observance of all requirements for the prevention of danger arising to public health from the meat as an article of food. After necessary communications with the responsible authorities of the countries concerned, the Board defined and published the "official certificates" which are to be accepted for this purpose (Circulars, 1909–10, Foreign Meat, Nos. 3, 4, 5, 6, and 7).

A further object of the Regulations is to provide means by which foreign meat generally which is diseased, unsound, unwholesome, or unfit for human consumption, may be detected and dealt with by public health authorities at the place of importation.

Powers of inspection for the purposes of the Regulations are conferred as for the Public Health (First Series: Unsound Food) Regulations, 1908. The Regulations require by Article III. (2) that the Officer of Customs shall cause to be detained, for examination by the **M.O.H.** of the **S.A.**, any foreign meat which according to the best opinion which, in the circumstances of the case, his knowledge enables him to form has the characteristics of foreign meat of either Class i. or Class ii. If he finds that the cargo comprises Foreign Meat of Class iii. or Foreign Meat Unclassed he may allow it to be removed unless he is of opinion that the meat requires examination by the **M.O.H.**

It is the duty of the **M.O.H.** to examine the meat and to give either a notice forbidding its removal for any purpose other than exportation, or a certificate that it may be removed. But he is not to give a certificate and must give a notice as regards Foreign Meat of Class i. or Class ii., and also as regards Foreign Meat of Class iii. or Foreign Meat Unclassed, if it is, in his opinion, notwithstanding the official certificate, diseased, unsound, unwholesome, or unfit for human consumption. (Definitions of meat detained or examined under these Regulations are furnished in a Circular of the **L.G.B.**, Dec. 12, 1908).

The **Notification of Births Act, 1907,** is an adoptive measure passed with the view of assisting indirectly in the reduction of infant mortality. It provides, where adopted, for notification in writing to the **M.O.H.** within thirty-six hours of the occurrence of a birth. The duty falls either on the father* of the child or any person attending the mother at the time of or within six hours of the birth. The **S.A.** is to supply without fee stamped forms of notification. Penalty for non-compliance is 20s. This notification is in addition to and not in substitution of ordinary birth registration. A certifiable birth is defined as "any child which has issued forth from its mother after the expiration of the twenty-eighth week of pregnancy whether alive or dead." The Act may be adopted by a resolution of the **S.A.** which must receive the sanction of the **L.G.B.** and be advertized in the district. Any **S.A.**, including County Councils except the County of London, may adopt the Act, or the **L.G.B.** may, by order, declare the Act in force in any area they think expedient. The Act has been adopted very widely in boroughs and urban districts.

The **Notification of Births (Extension) Act, 1915**, extended and made compulsory the Act of 1907 throughout the country. Under s. 2 it provides for making arrangements for the care of expectant mothers, nursing mothers, and young children, and with this object in view empowers the **S.A.** to co-opt women members and persons who are not members of the **S.A.**

The **London County Council (General Powers Act), 1907**, gives power to the **L.C.C.** to take samples of milk for examination for the presence of tubercle bacillus. If it be found, provision is made for inspection of cows, and cause must be shown by the dairyman why the sale of the milk should not be prohibited. If such a prohibition order be made without due cause, the dairyman is entitled to compensation. Every dairyman selling milk within the county must notify the presence of tuberculosis in his cows. The same Act provides for the examination of school children for uncleanliness and vermin, and, if necessary, compulsory cleansing of the body and clothing. The same powers are given for cleansing inmates of common lodging-houses.

Children Act, 1908.—This Act is a composite enactment to consolidate the law relating to infant life protection, the prevention of cruelty to children, reformatory and industrial schools, and juvenile offenders, with additional powers concerning juvenile smoking, the cleansing of verminous children, safety of children at entertainments, and giving intoxicating liquors to children.

Infant life protection. — Persons undertaking nursing and maintenance of one or more infants under 7 years of age must give notice to the local Authority, who shall inspect periodically and fix the number of infants which may be retained, and remove "to a place of safety" infants neglected or improperly kept.

Prevention of cruelty to children.—S. 12 imposes penalties for wilful assault, ill-treatment, neglect, abandonment, or exposure of children likely to cause suffering or injury to health (including injury to or loss of sight, or hearing, or limb, or organ of the body and any mental derangement). Neglect includes failure to provide adequate food, clothing, medical aid or lodging. Where it is proved that the death of an infant under 3 years of age was caused by suffocation in bed with some other person over 16 years of age (so-called "overlaid") and the other person was under the influence of drink, such person is deemed to have neglected the infant (s. 13). Penalties are also imposed on persons allowing children to beg, or reside in or frequent brothels, or be in rooms containing insufficiently protected fire-grates.

Children and intoxicating liquors. — Persons may not give intoxicating liquor to children under 5 years of age except on medical advice or urgent sickness, nor may the occupier of licensed premises allow a child under 14 years of age to be in the bar.

Cleansing of verminous children.—A local Education Authority may direct their medical officer or school doctor, or other person authorized by him in writing, to examine the person and clothing of any child attending a public elementary school; and if on examination the child is found to be infected with vermin, or is in a foul or filthy condition, the authority may give notice to the guardian or parent requiring the child to be cleansed within twenty-four hours. If the parent fails to comply, the child may be removed and properly cleansed in suitable premises and detained until cleansing is effected. If the **S.A.** have the use of cleansing appliances or premises, the education authority may use them for this cleansing. When a child so cleansed is allowed again to get filthy, the parent or guardian becomes liable to a summary conviction or a fine.

Public Health (Prevention and Treatment of Disease) Act, 1913.—S. 1 declares that, notwithstanding s. 281 of the Public Health Act, 1875, the **L.G.B.** may authorize a **S.A.** having jurisdiction in any part of a united district to exercise in relation to that part any powers which the joint Board are also authorized to exercise, subject to conditions and restrictions imposed by the Order.

S. 2 gives the **L.G.B.** power to declare that one of the authorities to execute and enforce regulations under s. 130 of the Public Health Act, 1875, with a view to the treatment of persons affected with cholera or any other epidemic, endemic, or infectious disease, and preventing the spread of cholera and such other diseases, shall be the County Council.

S. 3 makes it lawful for the County Council or any **S.A.** to make any such arrangements as may be sanctioned by the **L.G.B.** for the treatment of tuberculosis.

National Insurance Act, 1911.—Insurance against ill-health is compulsory under the Act for all employed persons between certain ages and within certain financial limitations, but persons in receipt of a pension of £26 or more, or who are ordinarily dependent on some other person, may claim exemption (s. 2). Further, any person under 65 who works on his own account or for other reasons is not obliged to be insured, may, subject to the income limit of £160, insure himself as a Voluntary Contributor (s 1). The contributions in return for which insured persons receive benefits under the Act are payable jointly by employers, insured persons, and the State, the State contributing two-ninths of the cost of benefits and their local administration in the case of men, and one-fourth in the case of women, as well as bearing the whole cost of central administration (ss. 3–7).

While insurance under the Act is compulsory, the individual insured person is not compelled to join an Approved Society, nor is any Society compelled to accept him as a member if it has any reason for not doing so. Insured persons who do not belong to an Approved Society are known as Deposit Contributors, and their contributions are credited to them in a "Deposit Contributors Fund." The governing principle of the scheme of Deposit Insurance is that the contributor is dependent for his benefits on his own contributions, increased by the usual Exchequer contribution. His benefits are administered by Insurance Committees, and are paid out of the sums standing to his credit in the Deposit Contributors Fund (s. 42).

The **benefits** conferred by the Act (s. 8) are—(1) *medical benefit:* medical treatment and attendance, including the provision of proper and sufficient medicines and such medical and surgical appliances as may be prescribed by regulations made by the Insurance Commissioners; (2) *sanatorium benefit:* treatment in sanatoria or other institutions or otherwise when suffering from tuberculosis, or such other diseases as the **L.G.B.** with the approval of the Treasury may appoint; (3) *sickness benefit:* periodical payments whilst rendered incapable of work by some specific disease, or by bodily or mental disablement, of which notice has been given, commencing from the fourth day after being so rendered incapable of work, and continuing for a period not exceeding twenty-six weeks; (4) *disablement benefit:* in the case of the disease or disablement continuing after the determination of sickness benefit, periodical payments so long as so rendered incapable of work by the disease or disablement; (5) *maternity benefit:* payment in the case of confinement of the wife or, where the child is a posthumous child, of the widow of an insured person, or of any other woman who is an insured person, of a sum of 30s.; (6) *additional benefits* (contingent upon the financial condition of the Approved Society), e.g.: (*a*) medical treatment and attendance for any persons dependent upon the labour of a member; (*b*) payment for dental treatment; (*c*) an increase of maternity benefit; (*d*) payments to members not allowed to attend work on account of infection.

Qualifying conditions are attached to the receipt of full benefits under the Act. There is a minimum period during which a contributor must have been in insurance, and a minimum number of contributions to be paid before a contributor is entitled to benefits, other than medical and sanatorium benefits (s. 8). Benefits are liable to reduction when insured persons are in arrear with their contributions, but allowance is made in cases where arrears are due to some particular hardship such as unemployment (s. 10). Sickness, disablement, and maternity benefits are administered, in the case of insured persons who are members of an Approved Society, by and through the Society, and, in the case of Deposit Contributors, by and through bodies set up under the Act in each county or county borough, called *Insurance Committees* (s. 14), by whom medical and sanatorium benefits are administered for all classes of insured persons (ss. 15, 16, 59).

In 1913 an amending Act was passed. This Act was prepared as a result of some eighteen months' experience in the administration of the 1911 Act, the chief objects being to secure (1) administrative simplification and economy; (2) improvement of the position of the insured person without incurring great additional expense. Under this Act persons who have claimed exemption from insurance may, subject to certain conditions, receive medical and sanatorium benefits, and by a further amending Act of 1917 these benefits are also made available, under conditions prescribed by the Insurance Commissioners, to *uninsured* discharged soldiers and sailors.

Administration of medical benefit.—Each Insurance Committee forms a panel of medical practitioners and also of the chemists in its area, who are willing to treat and serve insured persons at a scale of remuneration and under conditions agreed upon with the Committee. All arrangements made by the Committee are subject to the approval of the Commission (s. 15).

Originally, the sum of 6s. per insured person per annum was assumed as the cost of medical benefit—4s. 6d. for the payment of the doctor, and 1s. 6d. for drugs and appliances. In view of subsequent concessions this sum of 6s. was found to be inadequate, and was raised to 8s. 6d. A minimum of 6s. 6d.—or, taking into account a sum of 6d. allocated from sanatorium benefit funds for the domiciliary treatment of tuberculosis, a minimum of 7s.—was definitely assigned to the fund for the payment of the doctors, while the balance, 2s., was charged primarily with the cost of drugs, medicines, and appliances. Any residue of this balance up to 6d. reverts to the doctors, whose remuneration fund thus fluctuates between 7s. and 7s. 6d. per insured person.

Administration of sanatorium benefit.—Insurance Committees have charge of the administration of sanatorium benefit for all insured persons in their area who are entitled to such benefit, whether members of Approved Societies or Deposit Contributors, and for that purpose it is their duty to make arrangements, to the satisfaction of the Insurance Commissioners, for the treatment of such persons, when suffering from tuberculosis or such other diseases as the **L.G.B.** with the approval of the Treasury may appoint. Treatment for purposes of sanatorium benefit may be given (1) in sanatoria, hospitals, or other residential institutions, (2) at tuberculosis dispensaries, or other non-residential institutions, or (3) in the patient's home.

Insurance Committees are not empowered by the Act themselves to provide institutions. Their duty is to make arrangements with suitable persons or local Authorities (other than Poor-Law Authorities) for this purpose, and all such arrangements are required by the Act to be made to the satisfaction of the Commissioners. Moreover, the sanatoria or other institutions must be such as are approved by the **L.G.B.**, and the treatment to be given by persons or local Authorities, otherwise than in institutions, must be in a manner approved by the **L.G.B.** (s. 16).

Each Insurance Committee has, as its ordinary income for the provision of sanatorium benefit, a sum of 1s. 3d. per annum on account of each insured person for the administration of whose benefit the Committee is responsible. The sum of 1d. per insured person per annum provided by Parliament is applied to purposes of research (s. 16).

The Finance Act of 1911 made available a sum of £1,500,000 for the purpose of the provision of and making grants-in-aid to sanatoria and other institutions in the United Kingdom, which sum is apportioned between England, Wales, Scotland, and Ireland in proportion to their respective populations according to the census of 1911.

The Mental Deficiency Act, 1913.—The object of the Act is to make further provision for the care and control of certain classes of mentally lefective persons, viz. idiots, imbeciles, feeble-minded persons, and moral imbeciles. S. 1 defines the degree of mental defectiveness comprised in each class. Defectives can only be dealt with at the instance of a parent or guardian, except those who come within the categories set out in s. 2 (1) (*b*).

The methods of dealing with defectives are twofold: (1) the voluntary action of their parents or guardians (s. 3), and alternatively (2) the action of local Authorities, of Courts of criminal jurisdiction, or of the Secretary of State (ss. 5, 8 and 9). The Act sets up as Central Authority the Board of Control and defines its general powers and duties (ss. 21–26). Its local administration is placed in the hands of local Authorities (County and Borough Councils). Under s. 25 the Board of Control is empowered (1) to exercise general supervision and control over defectives, the administration by local Authorities of their powers and duties, and of their provision of institutional treatment and guardianship; (2) to visit defectives in institutions, homes, or under guardianship; (3) to provide and maintain institutions for defectives of dangerous or violent propensities; (4) to take such steps as may be necessary to ensure the provision of suitable treatment; (5) to make annual reports; and (6) to administer grants provided by Parliament. The general duties of local Authorities are briefly (s. 30) to ascertain what persons within their area are defective; to provide supervision and protection for them; to provide suitable and sufficient accommodation for persons sent to certified institutions, and guardianship for others, and to appoint officers and furnish annual or special reports to the Board of Control. The Secretary of State is empowered to make regulations with respect to the certification, approval, management, and visitation of institutions and homes and the treatment of patients detained or under guardianship, and to administer grants-in-aid.

Defective children.—Under ss. 2 (2) and 31 the duties of Local Education Authorities for dealing with defective children over seven years of age are laid down. The arrangements made by Local Education Authorities are subject to the approval of the Board of Education. They must ascertain what children within their area are defective and what children are incapable of receiving benefit in special schools or classes, and notify to local Authorities the names and addresses of such children.

In pursuance of the powers vested in them, the Board of Education issued the Mental Deficiency (Notification of Children) Regulations, 1914, and model arrangements under s. 1 (1) of the Elementary Education (Defective and Epileptic Children) Act, 1899, and s. 31 (1) of the Mental Deficiency Act, 1913. These regulations and model arrangements prescribed the procedure to be followed by local Education Authorities and such of their qualified Medical Officers (one of whom must be the School Medical Officer) as are approved by the Board of Education to act as certifying officers. It is their duty to examine every child referred to them by Head Teachers, School Attendance Officers, and Medical Officers as incapable of receiving benefit from the instruction provided, and furnish the local Education Authority with a certificate in prescribed form with a full report. The local Education Authority must then deal with the child, reporting to the Board of Control if it is incapable of education, providing for its education if it is capable of receiving benefit. (Elementary Education [Defective

CHAPTER XIX

THE HOUSING QUESTION

AMONG the chief factors affecting the health of a community is that of housing, regarding which there are two main issues—(1) the sufficiency, or otherwise, of house accommodation, and (2) the sanitation, or otherwise, of the existing accommodation. There is evidence that the population has grown proportionately more than the necessary dwelling-houses. In urban districts dwelling-houses have given way to business premises, or the increase of population by migration and births has outrun the number of new houses; in rural areas, worn-out, dilapidated, and closed cottage property has not sufficiently been replaced. There is thus a *shortage* of dwelling-house accommodation in town and country, which leads to many social and medical problems. In addition to shortage there is also much *insanitation* of such degree as to make the house unfit for habitation. Chief among such conditions are—bad structure; insufficient cubic capacity, lighting, or ventilation; absence of, or unsatisfactory, water supply or sanitary convenience; dampness; dilapidation; defective rain-water, waste, or closet drainage; or insanitary curtilage, outbuildings, or yard. The overcrowding of houses per acre, and their relative position to each other, may also make them uninhabitable.

Evidence of bad housing.—In representing to the **S.A.** the condition of housing in his area, the **M.O.H.** may be called upon to furnish evidence of unsatisfactory house accommodation, and in so doing he should not only be able to classify dwelling-houses (*see* p. 215) and report on each respectively, but should consider his area as a whole. The principal items of evidence are three: (1) structural signs of insanitation, named in the preceding paragraph; (2) the health, or otherwise, of the population accommodated; (3) social conditions (e.g. police returns, overcrowding, access to workplace). The effect of bad housing on the health is indicated: (*a*) By diminished personal cleanliness and hygiene, leading to debility, fatigue, unfitness, and diminished powers of resistance. The Housing Commission of 1885 reported that, in districts of poor housing, workmen lost on an average twenty days in the year from "exhaustion" and inability to work. (*b*) The sickness-rates are relatively high, particularly for infectious, contagious, and respiratory diseases. (*c*) The death-rates are high—zymotic, infant-mortality, and the general death-rate. The expectation of life is lowered. If and when such evidence presents itself the **M.O.H.** must report to the **S.A.** and make recommendations for remedial action.

While the housing problem is complex, and differs in different areas, the principal requirements are: (*a*) a sufficiency of convenient dwelling-houses at low rents, (*b*) adequate access to available and cheap land, and (*c*) improved means of communication. Since the Housing Commission of 1885 the Legislature has provided statutory means both for closure of houses unfit for habitation and for the erection of new ones. Thus the Housing of the Working Classes Act, 1890, was divided into several parts, dealing respectively with unhealthy areas, uninhabitable houses, and new accommodation. It was amended by the Act of 1909, which also provided in particular for facilitating town planning.

Housing of the working classes.—The principal objects to be kept in view are; (*a*) the improvement or clearance by the **S.A.** of unhealthy areas by means of improvement or reconstruction schemes or the removal of obstructive buildings, (*b*) the maintenance of house sanitation, and (*c*) the provision by the **S.A.** of sufficient and suitable houses for the working classes. Workmen's dwellings and tenement-houses are sanitary or insanitary usually on three grounds —construction, usage, and the relation of contiguous buildings.

(*a*) **Construction.**—The two possible types are the self-contained house and the tenement (or block of occupancies); the former is usually to be preferred. The number of houses to the acre will depend on the size, situation, and character of the site and the houses. Long rows and narrow frontages should be avoided, and small gardens or forecourts allowed for. The type of dwelling adapted to an ordinary working-class family of five persons should comprise a living-room, scullery (with bath), food store, three bedrooms, and necessary offices. The height of the rooms need not exceed 8½ ft., and the window area should be not less than one-twelfth of the floor area. Many workmen's dwellings are ill-constructed and without adequate sanitary provision.

(*b*) **Usage.**—Other workmen's dwellings become insanitary owing to misuse or domestic uncleanliness. In large towns the self-contained house becomes a tenement-house, and such misuse leads to insanitation; or a dwelling-house is used partly as a workplace, or is overcrowded, or the back yard or forecourt is built over or used for trade purposes.

(*c*) **Contiguous buildings.**—Where land is costly there is a tendency to overbuild per acre, and the houses obstruct each other. Factories are built, and, in effect, houses become "back to back."

Housing of the Working Classes Act, 1890.—Part I. deals with *unhealthy areas*, and is applicable in urban districts only. It is the duty of the **M.O.H.** to make an official representation to the **S.A.**, whenever he sees cause to do so, that within a certain area either (*a*) any houses or courts are unfit for habitation, or (*b*) the bad arrangement or condition of the streets or houses, or the want of light, ventilation, or proper conveniences, or any other sanitary defects, are dangerous to the health of the inhabitants, and that the evils cannot be effectually remedied otherwise than by rearrangement and reconstruction of some or all of the streets or houses. The **S.A.** must consider this representation, and if satisfied of the truth thereof, and of the sufficiency of their resources, must declare the area to be an *unhealthy area*, and frame an improvement scheme. The scheme may exclude any part of the area, or include any neighbouring lands. It must provide for proper sanitary arrangements, and may provide for widening the approaches, or otherwise opening out the area. Due publicity having been given to the scheme in a specified manner, application is to be made to the "confirming authority" for a provisional Order. The Confirming Authority (the **L.G.B.**), if it approves the scheme, directs a local inquiry to be held respecting the correctness of the official representation and the sufficiency of the scheme. In London, accommodation must be provided in or near the area for the whole number displaced, unless the Order decrees otherwise; under certain conditions the Order may accept in substitution equally convenient accommodation not in or near the area, and may dispense with the obligation to any extent not exceeding one-half. Outside the metropolis such provision is only compulsory if (and to the extent) prescribed by the Order. In assessing the value of property, no additional allowance for compulsory purchase is to be made in regard to any unhealthy portion of the area; and evidence may be given showing that the premises are (1) unfit for habitation, and cannot reasonably be made fit; or (2) in bad repair, or in an insanitary condition; or (3) that the rental is enhanced by reason of overcrowding or use for illegal purposes. In the first case the compensation is to be based upon the value of the land and building materials only; in the second, upon the value after allowing for the cost of necessary repairs; in the third, upon the value apart from such illegal use. After the provisional Order has been confirmed, it becomes the "Confirming Act," and is executed by the local Authority, who take steps to receive and adjudicate upon claims, if necessary submitting them to arbitration.

Upon complaint by two Justices, or twelve ratepayers, the **M.O.H.** must inspect and report upon any area. If he fails to do so, or reports that it is not an unhealthy area, such ratepayers may appeal to the confirming Authority, who may then appoint a medical practitioner to inspect the area. If the latter reports that it is an unhealthy area, the **S.A.** are required to prepare an improvement scheme. In any case, if the **S.A.** refuse or fail to prepare a scheme upon receipt of an official representation, they must report the facts to the confirming Authority, who may then order a local inquiry to be held.

Part II. applies to rural as well as urban districts, and relates to *unhealthy or obstructive dwellings*, and has been amended in the Act of 1909. Upon written complaint from four or more householders that any dwelling is unfit for habitation, the **M.O.H.** must inspect such house, and report to the **S.A.** If the **S.A.** (not being a rural **S.A.**, or in the county of London) fail to take action within three months, the complainants may appeal to the **L.G.B.**, who may, after local inquiry, order the **S.A.** to proceed. If the **M.O.H.** finds that any building—though not in itself unfit for habitation—by its proximity to other buildings, either (*a*) stops ventilation, or otherwise conduces to make them unfit for habitation, or (*b*) prevents the proper remedy of any nuisance or other evils in respect of such other buildings, he must make a representation to the **S.A.**, stating that in his opinion the obstructive building should be pulled down. A similar representation may be made by any four or more inhabitant householders. In either case the **S.A.** must make inquiry as to the facts, and as to the cost of acquiring the land and pulling down the building. If they decide to proceed, the **S.A.** can make an order for the demolition of the building, after giving the owner an opportunity of stating his objections, and subject to appeal to Quarter Sessions.

The **S.A.** may prepare a scheme for dedicating as a highway or open space, or appropriating or exchanging for the erection of working-class dwellings, the site of any building ordered to be demolished under Part II., if it appears to them that it would benefit the health of the inhabitants of the adjoining houses. They may also prepare an improvement scheme for any unhealthy area too small to be dealt with under Part I. Such schemes require confirmation by provisional Order of the **L.G.B.** after a local inquiry, and with or without modification. The Order may require provision to be made for the accommodation of persons of the working classes displaced.

In the County of London, Part I. is entrusted to the County Council and Part II. primarily to the Borough Councils.

Part III. authorizes the **S.A.** to provide lodging-houses for the working classes, subject to the sanction of the **L.G.B.** as regards urban authorities, and of the County Council in rural districts; and to make bye-laws respecting such houses. For the administration of this Part of the Act it was necessary up to 1909 for the **S.A.** to adopt it. Part IV. contains supplemental provisions.

Housing of the Working Classes Act, 1900.—This Act amended Part III. of the Act of 1890. It allows any Urban S.A. which has adopted Part III. to establish or acquire lodging-houses for the working classes outside their district.

An Urban **S.A.**, with the consent of the **L.G.B.**, and a Rural **S.A.**, with the consent of the County Council, may lease any land acquired by them under and for the purposes of Part III. to any lessee for the purpose and under the condition that the lessee will carry the Act into execution by building and maintaining on the land lodging-houses within the meaning of the Act.

The **Housing of the Working Classes Act, 1903,** extends the maximum period for the repayment of loans raised for the purposes of these Acts to 80 years (from 60), leaving the actual period for repayment, subject to this limitation, to be determined with the sanction of the **L.G.B.**

The Board propose as a general rule to allow the full term of 80 years for the repayment of loans for the purchase of freehold land, and 60 years for the repayment of loans for the erection of buildings, where the circumstances are such that this may properly be done.

The powers given to the Board to direct a local inquiry to be held, and a report made to them as to the correctness of the official representation (when the **S.A.** has taken no action) are supplemented by s. 4 (1) of the 1903 Act. If, on report made to them after inquiry, they are satisfied that a scheme ought to have been made for the improvement of the area to which the inquiry relates, or some part thereof, they can order the **S.A.** to make such a scheme (under either Part I. or Part II.).

A more speedy and efficacious way of obtaining possession of a house in respect of which a closing Order has been made than that provided by s. 32 (3) of the 1890 Act is afforded by s. 10 of the 1903 Act. Whatever the value or rent of the house, the **S.A.** may proceed either under ss. 138–145 of the County Courts Act, 1888, or under the Small Tenements Recovery Act, 1838. The expenses of proceedings can be recovered from the owner under the Summary Jurisdiction Acts.

S. 11 (1) empowers the **S.A.**, if they provide lodging-houses under Part III., or if they supply accommodation under the Housing Acts or under any scheme made in pursuance of these Acts, to provide and maintain in connexion therewith any building adapted for use as a shop, any recreation-grounds, or other buildings or land which, in the opinion of the Board, will serve a beneficial purpose in connexion with the requirements of the persons for whom the lodging-houses or dwelling accommodation are provided. The consent of the Board is required to the exercise of these powers, and they may require statutory provisions of control.

Service of notices.—The service of notices and other documents is facilitated by s. 13.

Housing, Town Planning, etc., Act, 1909.—The principal provisions in regard to **housing** are contained in Part I. and the First Schedule to the Act. They may be summarized as follows:—

(1) Part III. of the Housing of the Working Classes Act, 1890, which was formerly adoptive only and enables local authorities to provide houses for the working classes is now put in force throughout the whole country. (2) The new Act greatly increases the facilities for the compulsory acquisition of land (by means of **L.G.B.** Order) for the purposes of Part III. of the Housing Act, and the acquirement by agreement of land not immediately required for housing. (3) Loans can in future be made by the Public Works Loan Commissioners for periods up to 80 years at the minimum rate of interest allowed for the time being for loans out of the Local Loans Fund, and the rate of interest will not vary with the term allowed for repayment (s. 3). (4) Powers are given to the **L.G.B.** for the enforcement of the execution of the Housing Acts (s. 10), which are very complete as regards all matters concerning the housing of the working classes, and to require schemes to be carried out within a limited time. Powers are also conferred on County Councils to act in default of rural districts (s. 12). (5) The new Act (s. 14) extends to houses of much higher rental (£40 in London, £26 in towns, £16 in country) than those fixed by s. 75 of the Act of 1890, the condition implied, in the contract for letting, being that the house is fit for habitation, and that the landlord shall keep the house in a state reasonably fit for habitation

during the holding. S. 15, which requires landlords to keep houses within the rental limits above referred to in all respects reasonably fit for human habitation, gives powers to the local Authority in regard to landlords who make default in this respect. (6) The law as regards the closing and demolition of insanitary dwellings has been simplified and strengthened. It is the duty of every **S.A.** to cause *inspection of the district* to be made with a view to ascertain whether any dwelling-house therein is in "a state so dangerous or injurious to health as to be unfit for human habitation"; and if on the representation of the **M.O.H.**, or any other officer of the **S.A.**, or other information given, any dwelling-house appears to the **S.A.** to be in such a state, the **S.A.** (without appeal to a Court of summary jurisdiction, as formerly) shall make a "*closing order*" prohibiting its use until rendered fit for human habitation. Notice shall be served on the owner and tenants. The closing order shall be determined when the **S.A.** are satisfied that the house has been made habitable, but failing this the **S.A.** shall after three months take into consideration the question of the *demolition* of the house, and after hearing evidence from all concerned the **S.A.** may themselves order demolition. Appeal may be made to the **L.G.B.** (7) Other important provisions to which attention should be drawn are those contained in s. 16, which extends the power of making bye-laws for lodging houses; in s. 17 (7), under which underground rooms habitually used as sleeping places must comply with regulations prescribed by the **S.A.** or the **L.G.B.**; in s. 43, which *prohibits* the erection of back-to-back houses; in s. 81, which shortens the period for demolition of closed houses; and in s. 24, the effect of which is that schemes under Part I. or Part II. of the Act of 1890 will take effect on the issue of the Board's Order confirming them, and will not need confirmation by Parliament. S. 36 considerably enlarges the power of entry on premises for the purposes of the Housing Acts for survey, examination, and valuation, s. 38 provides for joint action of local authorities, and s. 44 enables the Board to deal with bye-laws with respect to new streets or buildings if the erection of dwellings for the working classes is unreasonably impeded in consequence of them.

The Board have framed Rules under s. 39 with regard to the procedure on appeals to them under the Housing Part of the Act, and also forms of notices, advertisements, and other documents under s. 41 (1). They have also framed Regulations under s. 17 for effective inspection. (*Housing [Inspection of District] Regulations*, 1910.)

Town planning.—The object of the Town Planning Part (II.) of the Act is to ensure, by means of schemes which may be prepared either by local authorities or landowners, that, in future, land in the vicinity of towns shall be developed in such a way as to secure proper sanitary conditions, amenity and convenience in connexion with the laying out of the land itself and of any neighbouring land. Hitherto the conflicting interests of different owners and the absence of any power in the local Authority to guide and control development according to the circumstances and requirements of particular cases have resulted to a considerable extent in the development of estates, whether large or small, with a sole regard to the immediate interests of the particular estate and without regard to the amenity and convenience of neighbouring lands. Much has, of course, been done by provisions in public general statutes, bye-laws, regulations, and local Acts to secure sanitary conditions in the development of land. But such provisions, which commonly apply to a whole district, are inherently inelastic in their character and are not concerned with amenity and convenience as affected by the particular circumstances of the actual land about to be developed. The Town Planning Part of the new Act involves a material advance in these matters and in the relations between the owners of land and the local Authorities, and enables each party to co-operate with the other in promoting the general interest.

A **town planning scheme** may be made "as respects any land in course of development or likely to be used for building purposes, with the general object of securing proper sanitary conditions, amenity and convenience." The **L.G.B.** may authorize a **S.A.** to prepare a scheme in their area if there is a prima-facie case, or adopt a scheme, with or without modification, proposed by owners of land. All schemes must be approved by the Board, who may prescribe the contents of the scheme and make Regulations of procedure (Town-Planning Procedure Regulations, 1910, amended 1914). The steps to be taken in any area are (*a*) consideration as to advisability of preparing a scheme, (*b*) application for permission to prepare a scheme, (*c*) the preparation of the scheme in accordance with the Regulations, and (*d*) the approval of the scheme by the **L.G.B.** and its executive. The importance of co-operation is fully recognized by the Act. Thus s. 56 (2) contemplates that the Regulations to be made by the Board under that section shall provide for securing this co-operation by means of conferences and otherwise at every stage. Again, amongst the matters to be dealt with by General Provisions under s. 55 is the power of the responsible authority to make agreements with owners, and of owners to make agreements with one another (paragraph 13 of Fourth Schedule). Considerable powers are conferred on the **S.A.** to enforce schemes (s. 57), to make compensation in respect of property injuriously affected by planning schemes (s. 58), and to acquire land for such schemes (s. 60). Powers are also conferred on the **L.G.B.** to make or execute schemes in default of the **S.A.** (s. 61). Lastly, by s. 68, it is obligatory upon every County Council to appoint a **M.O.H.**, whose duties shall be prescribed by the General Order of the **L.G.B.** Certain sections of the 1890 Housing Act are repealed to allow of the modifications named above. Under this Act, from 1911 to 1916, 123 schemes by Authorities, comprising areas containing 208,000 acres, were approved. The **L.G.B.** issue an annual statement of action taken under these Acts.

Some progress has been made by private enterprise, co-operative agencies, and the local Authorities in supplying new accommodation, but much remains to be done to secure a minimum of healthy provision. Private enterprise has established "model" villages at Bournville, Earswick, Knebworth, Port Sunlight, and elsewhere; co-operation is represented at Hampstead, Harborne, Hereford, etc.; and municipalities undertaking schemes include Birmingham, Rochdale, Croydon, and Leeds. Delay has been caused by large social issues such as wages, economic rent, tied houses, urbanization, absence of impulse, city extensions, and the high cost of land, labour, and building materials.

CHAPTER XX

FACTORIES AND WORKSHOPS

INCIDENTAL reference has been made in Chapters XVII. and XVIII. to the powers and duties of the **S.A.** with regard to industrial premises. Large additions are made by the Factory Acts, and in stating these it will be convenient to refer briefly to some of the leading points in industrial hygiene, and to indicate generally the division of responsibility between the local and central Authorities.

The **Factory and Workshop Acts, 1901 and 1907,** which apply to some 123,000 factories and 154,000 workshops, giving employment ordinarily to 6,000,000–8,000,000 workpeople, are administered chiefly by H.M. Inspectors of Factories, but also in important particulars by the **S.A.** The latter are charged with duties as to (1) sanitation of workshops (and, in certain particulars, factories also), (2) bakehouses, (3) home work, and (4) means of escape from fire. Many of these fall to the **M.O.H.,** upon whom are placed further duties of reporting.

Factories include (1) works in which mechanical power is used in aid of a manufacturing process, or in quarries, *pit-banks* of metalliferous mines, dry cleaning, carpet-beating or laundries; and (2) the following, whether power be used or not, viz. *print works*, *bleaching and dyeing works*, *earthenware works*, *lucifer-match works*, *percussion-cap works*, *cartridge works*, *paper-staining works*, fustian-cutting works, *blast furnaces*, copper mills, *iron mills*, *foundries*, *metal and indiarubber works*, paper mills, glass works, tobacco factories, letterpress-printing works, bookbinding works, flax-scutch mills, *electrical stations*. Those in italics are technical expressions, defined in the Act.

A *tenement factory* is one in which mechanical power is supplied to different parts of the same building occupied by different persons for the purpose of any manufacturing process or handicraft in such manner that these parts constitute in law separate factories.

Workshops include (1) the following, unless they are factories by reason of use of mechanical power, viz. hat works, *rope works*, *bakehouses* ("any places in which are baked bread, biscuits, or confectionery from the baking or selling of which a profit is derived"), *lace-warehouses*, *shipbuilding yards*, *quarries*, *pit-banks of* metalliferous mines, dry-cleaning works, carpet-beating works, bottle-washing works, and laundries.

(2) Premises (not being factories) in which manual labour is exercised by way of trade or for purposes of gain, in or incidental to the making, altering, repairing, ornamenting, finishing or adapting for sale of any article, *if the employer has the right of access or control.*

(3) *Tenement workshops*: that is, workplaces in which, "with the permission of or under agreement with the owner or occupier, two or more persons carry on any work which would constitute the workplace a workshop if the persons working therein were in the employment of the owner or occupier."

There may be several distinct factories or workshops, each comprising one or more rooms in different occupation, in the same building.

Domestic factories and *domestic workshops* are those carried on in private houses without use of mechanical power, where the only persons employed are members of the same family dwelling there. If any work certified by the Home Secretary to be dangerous is carried on they are treated as ordinary factories and workshops: otherwise they are, so far as sanitation is concerned, treated as ordinary *workshops*, except that the requirements as to general ventilation and drainage of floors do not apply.

The following, if carried on under conditions which would otherwise make the premises a domestic workshop, are exempted:—

(1) Straw-plaiting, pillow-lace making, glove-making.

(2) Work done at irregular intervals and not furnishing the principal means of living to the family.

Men's workshops (those in which only males over 18 are employed) are exempted from several of the provisions of the Act, including those relating to general ventilation, temperature, drainage of floors, sanitary accommodation, lavatories, fans for removal of dust or fumes, and means of escape from fire.

Crown factories and workshops are excluded from the jurisdiction of the **S.A.**

Workplace is not defined, but has a wider meaning than workshop, and has been held to include any place where people assemble together to do work permanently, e.g. a stable and stableyard where men were employed as cab-cleaners and horse-keepers.

In *workshops and workplaces* the **S.A.** are primarily responsible for enforcing sanitary requirements generally, and means of escape from fire; and their officers have the same powers of entry, inspection, and legal proceedings as Inspectors of Factories. Certain sanitary requirements, however, more particularly those relating to temperature, fans for removal of dust and fumes, and those arising under the Factory Act (as distinguished from the powers of the **S.A.** under the P.H. Acts) with regard to sanitary accommodation, are enforced by the Factory Inspectors. The **S.A.** are required to keep a register of all workshops in their district. If the **M.O.H.** finds any woman, young person, or child employed in a workshop in which no abstract of the Factory Acts is affixed, he is required to inform the Factory Inspector. The occupier of a new factory or workshop must notify the Factory Inspector, who, in the case of a workshop, forwards the notice to the **S.A.**

In *factories*, sanitation generally is enforced by the Factory Inspector, not by the **S.A.**, but the latter deal with means of escape from fire (in London this rests with the County Council), and sanitary accommodation (under the P.H. Acts only), and have special duties in connexion with bakehouses and domestic factories.

If any act or default, punishable or remediable under the P.H. Acts but not under the Factory Acts, is found by the Factory Inspector in a factory or workshop, he is to report it to the S.A., who must make inquiry, take such action as may seem proper, and inform the Factory Inspector what has been done. If proceedings are not taken by the **S.A.** within a month, the Factory Inspector may institute proceedings in default, and recover from the **S.A.** any expenses not recovered from other persons, and not incurred in unsuccessful proceedings. If the **S.A.** fail generally to carry out their duties with regard to factories, workshops or workplaces, the Home Secretary may authorize the Factory Inspector to act in default for a specified period, and the expenses not recovered from other persons (and not incurred in unsuccessful proceedings) may be recovered from the **S.A.**

The **M.O.H.** is required in his Annual Report to report specifically upon the administration with regard to workshops and workplaces, and to send a copy to the Home Secretary. A table issued by the **L.G.B.** for the guidance of the **M.O.H.** includes the items calling for statistical record.

Outside the Factory Acts (which are directed to the protection of the workers), the **S.A.** are concerned with certain factories and workshops on public health grounds, as sources of smoke, poisonous fumes, trade effluents; as places where offensive trades or food manufacture needing control are carried on; as new buildings needing approval of plans, or old buildings in a dangerous state; or more indirectly as places in which infection may be spread from one person to another, or (as in laundries) infected articles may be handled.

Nor are these the only points claiming the attention of architects, builders, and **S.A.**s in connexion with plans for new factories and workshops. Others are strength of foundations and structure generally where heavy machinery is to be fixed; means of escape from fire; sanitary accommodation. Others, again, are the statutory requirements as to air-space, ventilation, and warming; the surfaces of walls and ceilings must be such as to admit of due cleansing; and the proper construction of floors (soundness, impermeability, slope, and drainage) is of importance in certain processes. In certain dangerous trades additional structural requirements (lavatories, baths, mess-rooms, cloakrooms, etc.) arise, and in some the plans have also to be approved by the Chief Inspector of Factories.

Cleanliness.—Workshops and workplaces must be kept in a cleanly state; and a workshop, or any specified part thereof (in London, a workplace or domestic factory also), must be limewashed, cleansed, or purified when so required by notice from the **S.A.** on a certificate of the **M.O.H.** or Sanitary Inspector that it is necessary for the health of the workers.

Factories must be kept in a cleanly state and (subject to certain exceptions) either (*a*) limewashed every 14 months, or (*b*) painted with oil or varnished every 7 years, and washed with soap and hot water every 14 months.

For the cleaning of floors, etc., damp processes are preferable, as checking the production of dust.

Air-space.—Factories, workshops and workplaces must not be so overcrowded as to be dangerous or injurious to the health of the workers, and there must be at least 250* cub. ft. of air-space for each worker. The air-space of each workroom must be stated in a notice affixed in the works.

A much larger air-space is required in certain dangerous trades, and in works where certain special exceptions are permitted—e.g. in rooms in which wool liable to contain anthrax spores is sorted the minimum is 1,000 cub. ft., and in engineering works exemption from routine annual limewashing is allowed if the air-space be 2,500 cub. ft. per head.

General ventilation must be efficient in every workroom of a factory or workshop (other than a men's workshop). Standards † of ventilation are prescribed for certain workrooms. A departmental Committee in 1902 recommended a general limit for workrooms of 12 parts of CO_2 per 10,000.

Air samples are usually taken at the breathing level, at points where work is carried on, and not in extreme corners or

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[*] 400 during overtime of women, 500 in underground bakehouses, 400 between 9 p.m. and 6 a.m. in other bakehouses with light other than electric, 400 in workshops (not domestic) used also as sleeping-rooms.

[†] E.g.—A limit of 9 vols. CO_2 per 10,000 in humid cotton-cloth factories, and in flax, hemp, and jute works, and 600 cub. ft. fresh air per head per hour in other humid textile factories.

near to inlets or outlets, or close to persons or to sources of CO_2. In breweries, aerated-water factories, bakehouses, etc., where CO_2 is given off by trade processes, allowance has to be made; and similarly where artificial lighting yields CO_2. As a rule it is well to make a parallel determination in the open air.

Mechanical ventilation by fans may be either on the plenum or vacuum system. The number, position, dimensions, and speed of the fans are matters requiring expert knowledge; as a rule better results are obtained by large fans moving slowly than by small fans at a high speed. Plenum is on the whole preferable, and offers facilities for warming, screening, or humidifying the air when necessary. Exhaust ventilation calls for care in guarding against indraught through closets or other unsuitable channels. Paddle fans, which churn the air without changing it, are not to be regarded as means of ventilation, though the currents they cause may promote evaporation, and thus have some cooling effect. If reliance is placed on "natural" ventilation (whether by chimneys, open windows and doors, ventilators or shafts), supervision becomes necessary, especially in cold weather. In any case care should be taken to secure ventilation of all parts of the room, to avoid short-circuiting and direct draughts upon workers, and to provide adequately for both inlets and outlets. (*See also* p. 192.)

Local ventilation for removal of dust, gases, vapours, or other impurities generated in the course of work, which are injurious to health, must be such as to render them harmless as far as practicable.

Usually this involves *exhaust ventilation,* applied at or near the point of origin; and fans (or other efficient mechanical means) for the purpose are prescribed in certain dangerous processes, and can be required by the Factory Inspector in others. Exhaust ventilation may sometimes be secured by connexion with flues or other heated shafts. The essentials are (1) that the dust or fumes should be intercepted as near as possible to their source, and carried away from the workers, without entering the general air of the room; (2) that the draught should be adequate for the purpose, and guided where necessary by hoods; and (3) that the air-ducts should be kept clean and discharge at a suitable point, preferably in a closed dust-chamber. As a rule a downward draught is best, since it carries away the dust more readily. The efficiency of exhaust can be tested by anemometer, or by smoke, light dust, or fumes of ammonium chloride. In some instances standards are fixed, in terms of sectional area of openings and velocity at given points.

Other precautions in dusty processes are the use of closed chambers or boxes, the adoption of wet processes, handling the dusty materials over gratings through which the dust can fall, cleanliness of premises and floors, the use of overalls, (if the dust be poisonous) prohibition of taking food in the workroom, and provision of suitable lavatories.

As a last resource *respirators* may be adopted, especially where the occupation is intermittent, but there is difficulty in enforcing the systematic use of them, and most of them entail some physical discomfort if worn for long periods or in heavy work. The essentials in a respirator are that it should be light, simple, inexpensive, the filtering material readily renewed or cleaned; that it should be as little unsightly as possible; that it should arrest all dust, filter the whole of the inspired air, and prevent the rebreathing of expired air; and that it should offer the minimum resistance to the free passage of air without respiratory effort, and without becoming obstructed in use by moisture from the breath. A fold of cambric covering the mouth and nostrils is an efficient simple respirator. Many elaborate forms fail when tried under the actual conditions of the work for which they are proposed.

Some kinds of dust are directly infective, e.g. anthrax, tetanus, smallpox (among rag-sorters in paper works and elsewhere); others poisonous (e.g. lead, mercury); and others, again, mechanically injurious in varying degree. Similarly the wide variety of gases, fumes, and vapours which arise in manufacturing processes and require removal include many which are directly poisonous (e.g. CO, CS_2, H_2S, SO_2, chlorine, nitrous and other acid fumes, AsH_3; lead, zinc and mercury fumes), and some which are harmful in other ways (e.g. steam) or offensive (organic effluvia).

Explosion may arise from ignition of inflammable dust or fumes mixed with air: e.g. ordinary gas, marsh gas (in coal mines); naphtha, coal dust, or celluloid borings.

Temperature.—In every workroom of a factory or workshop provision must be made for securing a reasonable temperature, and without interfering with the purity of the air of the room. This requirement is enforced by the Factory Inspector. Gas jets cannot be accepted as means of warming, nor must the ventilators be closed. Flueless stoves are objectionable, owing to the risk of adding sulphur compounds, CO, and other impurities to the air.

As a lower limit 60° F. is suitable for sedentary occupations involving little exertion, but active work can be carried on, indoors as well as in the open air, at lower temperatures. The upper limit is not easily defined, since in certain processes a high temperature is a trade necessity, while in others it is only accidental (e.g. from use of furnaces, consumption of gas, moving machinery, steam pipes), and calls for preventive measures such as free ventilation, screening off sources of heat, "lagging" of hot pipes and reducing their dimensions as far as practicable. In humid cotton-cloth factories the prescribed precautions of the kind include whitewashing of the roof in summer, and it is forbidden to raise the temperature artificially above 70° F., except so far as is necessary in humidifying.

If the air be dry enough, high temperatures can be borne, but as a matter of health as well as comfort high wet-bulb temperatures (over 75°) are to be avoided as far as possible, especially where the work is hard.

Humidity is expressly regulated in humid textile factories generally,* a limit (of relative humidity, that is, per cent. of saturation) being fixed for each dry-bulb degree: 88 per cent. from 59° to 70°, decreasing thenceforward to 77·5 per cent. at 80°, 69 per cent. at 90°, and 64 per cent. at 100°. In certain textile processes, however, a difference of 2° between wet and dry bulb is accepted at all temperatures. Hygrometers must be affixed in each room, and (except in cotton spinning) records kept of two (in cotton-cloth factories three) daily readings at [7 to 8 a.m.], 10 to 11 a.m., and 3 to 4 p.m. The water used for humidification must either be taken from a pure source or be effectively purified; a water which gives off offensive gases of any kind on heating, or which absorbs from acid solution of $KMnO_4$ at 60° F. in 2 hours more than 0·5 mg. of oxygen, is regarded as unsuitable. In moist air the clothing becomes damp, and warmed ventilated cloak-rooms are obligatory in new humid cotton-weaving factories.

Steam in excess arises incidentally in laundries, dyehouses, etc., and can be removed by exhaust ventilation or by introducing hot dry air.

Lighting is only regulated by the Factory Act as regards underground bakehouses (p. 679) and, by special Orders, in certain dangerous trades. For artificial lighting electric light or ventilated gas-burners are preferable, as they do not add to the impurity of the air or call for additional ventilation. (*See* Report on Lighting in Factories, etc., 1915, Cd. 8000.)

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* Spinning and weaving factories in which the air is artificially humidified by steam jets or otherwise, in order to correct the dryness of the air, which beyond a certain limit interferes with the treatment of the fibre.

Floors have to be sound and impervious for the purpose of certain dangerous processes, and to be drained in wet processes generally (except in men's workshops) and especially in laundries.

Sanitary accommodation is enforced by the **S.A.** in both factories and workshops, in London (Public Health Act, 1891, s. 38) and where s. 22 of the P.H. Acts Amendment Act of 1890 is in force. Elsewhere the **S.A.** have similar powers under s. 38 of the P.H. Act, 1875; but s. 9 of the Factory Act also, applies, and the administration of this (and of the Order which interprets it) rests with the Factory Inspector alone.

The *Factory and Workshop Act*, 1901, *s.* 9, requires that "every factory and workshop must be provided with sufficient and suitable accommodation in the way of sanitary conveniences, regard being had to the number of persons employed or in attendance at the factory or workshop, and also where persons of both sexes are or are intended to be employed or in attendance, with proper separate accommodation for persons of each sex," and gives power to the Home Secretary to determine by Order what is sufficient and suitable accommodation within the meaning of the section.

Accordingly the *Sanitary Accommodation Order of February 4th*, 1903, directs that:—

"1. In factories or workshops where females are employed or in attendance there shall be one sanitary convenience for every 25 females.

"In factories or workshops where females are employed or in attendance there shall be one sanitary convenience for every 25 males; provided that—

"(*a*) in factories or workshops where the number of males employed or in attendance exceeds 100, and sufficient urinal accommodation is also provided, it shall be sufficient if there is one sanitary convenience for every 25 males up to the first 100, and one for every 40 after;

"(*b*) in factories or workshops where the number of males employed or in attendance exceeds 500, and the District Inspector of Factories certifies in writing that by means of a check system, or otherwise, proper supervision and control in regard to the use of the conveniences are exercised by officers specially appointed for that purpose, it shall be sufficient if one sanitary convenience is provided for every 60 males, in addition to sufficient urinal accommodation. Any certificate given by an Inspector shall be kept attached to the general register, and shall be liable at any time to be revoked by notice in writing from the Inspector.

"In calculating the number of conveniences required by this Order, any odd number of persons less than 25, 40, or 60, as the case may be, shall be reckoned as 25, 40, or 60.

"2. Every sanitary convenience shall be kept in a cleanly state, shall be sufficiently ventilated and lighted, and shall not communicate with any workroom except through the open air or through an intervening ventilated space; provided that in workrooms in use prior to 1st January, 1903, and mechanically ventilated in such manner that air cannot be drawn into the workroom through the sanitary convenience, an intervening ventilated space shall not be required.

"3. Every sanitary convenience shall be under cover and so partitioned off as to secure privacy, and if for the use of females shall have a proper door and fastenings.

"4. The sanitary conveniences in a factory or workshop shall be so arranged and maintained as to be conveniently accessible to all persons employed therein at all times during their employment.*

"5. Where persons of both sexes are employed, the conveniences for each sex shall be so placed or so screened that the interior shall not be visible, even when the door of any convenience is open, from any place where persons of the other sex have to work or pass; and, if the conveniences for one sex adjoin those for the other sex, the approaches shall be separate."

Other sanitary requirements.—*Lavatories* are required where any poisonous substance is used. For certain dangerous trades details are prescribed, e.g. that there shall be soap, nail-brushes, towels, and at least one basin (with hot water supply and waste pipe) for every 5 persons. In some, baths also are required. *Cloak-rooms* are obligatory in new humid cotton-cloth factories, and where certain dangerous trades are carried on.

In certain rooms, e.g. where poisonous substances are so used as to give rise to dust or fumes, it is forbidden to take food or to remain during meal hours, and accommodation for meals must be provided elsewhere on the premises.

Dangerous trades, certified as such by the Home Secretary, are further subject to regulations (of automatic application) or special rules (established in individual works) issued by the Home Office. These prescribe additional precautions, according to the nature of the danger, and are enforced by the Factory Inspectors. The Acts allow certain special exceptions, which are often coupled with additional requirements, sanitary and other; these also are administered solely by the Factory Inspectors.

Certifying surgeons are appointed for every locality. Their duties include (1) examination of children and of young persons under 16 for certificates of fitness for employment in factories and certain workshops, (2) investigation of diseases and poisoning, (3) periodical examination, when required by regulations or special rules, of persons employed in processes entailing danger of poisoning.

The dangers to health against which the above provisions are directed are obvious, but there are, of course, many others of a different kind, not limited to employment under the Factory Act. Thus coal miners are liable to nystagmus from working in constrained positions, and to "beat hand" and "beat knee" (chronic inflammation due to local pressure); men working in compressed air to "caisson disease" if care be not taken to pass slowly from higher to lower pressures, through air-locks. Writer's cramp, Dupuytren's contraction, housemaid's knee, the emphysema of performers on wind instruments, are other examples. Hernia or aneurysm may be determined by violent exertion; carrying unduly heavy weights is injurious, and is indirectly prohibited as regards girls under 18 as a condition of special exception as to hours in fruit preserving. Sight may suffer from strain in fine work in inadequate light, and cataract is common among glass workers. Habitual exposure to weather in open-air occupations, and violent alternations of temperature in connexion with furnaces or otherwise, present dangers of their own.

Means of escape from fire.—Factories built after 1891, and workshops built after 1895, must, if more than 40 persons are employed, have a certificate from the **S.A.** as to reasonable adequacy in this respect, specifying in detail the means provided. In older works with more than 40 hands the **S.A.** must see that reasonable provision is made, and if not, must require the owner by notice to carry out specified details in a specified time: any dispute to be settled by arbitration. The whole of a tenement factory or tenement workshop is counted as one. The **S.A.** may, subject to confirmation by the **L.G.B.**, make bye-laws as to means of escape in any factories or workshops. In London these duties rest with the County Council.

Doors of workrooms must not during working hours be fastened so as not to be readily opened from inside, and in works built after 1895, doors of rooms in which more than 10 persons are employed must not open inwards.

Adequate means of escape are all the more essential where the nature of the manufacture entails special risk of fire. Alternative paths of escape are desirable (since the main line of exit may be readily involved in the fire) especially where large numbers are employed, and these paths should be obvious and kept clear of unnecessary obstruction.

Laundries are technically factories or workshops. In *factory* laundries fans are required for regulating the temperature of ironing-rooms, and for removing steam from wash-houses; and in all laundries (*a*) stoves for heating irons must be sufficiently separated from the ironing-room or ironing-table, and gas-irons emitting noxious fumes must not be used; (*b*) floors must be kept in good condition and so drained as to allow the water to flow off freely.

Bakehouses are factories or workshops, but subject to certain special requirements as below. *Retail bakehouses* are workshop bakehouses in which the articles baked are sold by retail only in a shop occupied therewith. *Underground bakehouses* are those in which any room used for baking or processes incidental thereto has its floor more than 3 ft. below the footway of the adjoining street or ground adjoining or nearest to the room.

If a bakehouse is on sanitary grounds unfit for that use, a Court may, on application by the Factory Inspector or **S.A.**, impose a penalty and require the necessary alterations to be made. It must not contain or communicate directly with a closet, nor derive its water supply from a cistern supplying a w.c. A drain or pipe for carrying off fæcal or sewage matter must not have an opening in the bakehouse (thus any waste-pipe must be disconnected outside). The walls and ceilings of rooms, passages, and staircases must be limewashed every 6 months; or receive three coats of oil-paint or varnish every 7 years, and be washed with hot water and soap every 6 months. A part of the same building, on the same level with the bakehouse, must not be used as a sleeping-room unless partitioned off from floor to ceiling, and having an external glazed window 9 sq. ft. in area, 4½ ft. of which is made to open.

An underground bakehouse must not be used as such unless (*a*) it was so used on August 17th, 1901, and further (*b*) the S.A. has certified it to be suitable as regards construction, light, ventilation, and in all other respects.

The administration of these special requirements in retail bakehouses (in London in all workshop bakehouses, and the certification of underground bakehouses) rests with the S.A. In other cases the Factory Inspector and S.A. have concurrent powers.

Food premises.—A high standard of sanitation is needed in premises where food is manufactured, prepared, cooked, or stored; including bakehouses, restaurant kitchens, ice-cream premises, fish-shops, meat-shops, preserved meat works, confectionery works, dairies and milkshops. The following **summary** may serve to indicate generally the chief points needing attention:—

(1) Surfaces of floors, walls, and ceilings to be hard, smooth, durable, and impervious. Floors to be laid to proper falls, and drained by proper channels to a gully outside.

(2) Any drain beneath the floor to be gas- and water-tight. All pipes and fittings to be efficient.

(3) Walls to be absolutely dry; failing this, to have an inner wall at least ½ in. thick, tied to the outer wall, but with 2-in. ventilated and drained intervening space.

(4) Minimum height 8 ft.; minimum air-space 400 cub. ft. per head and 1,500 cub. ft. in all, clear of ovens, machinery, and stored goods.

(5) Efficient lighting: where practicable, natural light only; among artificial lights electric is preferable, or, if gas is necessary, incandescent burners protected from dust and ventilated to remove fumes.

(6) Ventilation, by fan if necessary; ensuring constant and sufficient change of air without draughts, and a temperature not ordinarily exceeding 60° F., or 80° F. at any time except within half an hour after "drawing" an oven.

(7) Oven furnaces to have efficient flues to carry away fumes. An outlet for heat and steam immediately before and above the oven door. Oven doors and outer doors of furnaces to fit closely. Proving ovens to be efficiently ventilated. If gas is used for heating, means of removing fumes. Hoods and ducts leading to the open air, over stoves and ranges.

(8) Strict cleanliness of premises and appliances.

(9) Water supply, with jet and hose, for washing floors; cisterns (if any) to be of proper construction, with dust-tight covers, and kept clean.

(10) Tables, benches, dough-troughs, etc., to be freely movable on casters.

(11) Any necessary shelves to be fixed 2 in. away from walls, but unnecessary woodwork on walls to be avoided.

(12) Suitable provision, outside the workroom, for storage of food materials (milk in clean covered vessels, in a cool place); storage of fuel; deposit of clothing not in use; lavatory; sanitary accommodation. Covered sanitary bins for refuse.

Home work of certain kinds* defined by Order (Home Work Order of April 10th, 1911) of the Home Secretary is under special control. The employer must keep a list of the names and addresses of the outworkers, and send copies to the **S.A.** of his district on or before February 1st and August 1st of each year, in a prescribed form. If any such addresses are outside the area of the **S.A.**, particulars of them must be sent by the **S.A.** to the **S.A.** concerned. If the home premises are injurious or dangerous to the health of the workers, the **S.A.** may prohibit the employer from giving out work to be done there.

If an inmate of the house is suffering from a notifiable infectious disease (even if he has been removed) the **S.A.** may by order prohibit the employer from giving out work to be done in that house or in any specified part of it, during a specified term. This power

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[*] The making, cleaning, washing, altering, ornamenting, finishing, and repairing of wearing apparel; the making, ornamenting, finishing, and repairing of table linen, bed linen, or other household linen; the making, ornamenting, mending, and finishing of lace and of lace curtains and nets; the making of curtains and furniture hangings; upholstery work; fur-pulling; the making or repairing of umbrellas, sunshades, parasols, or parts thereof; the making of artificial flowers; the making of nets other than wire nets; the making of tents; the making or repairing of sacks; the covering of racquet or tennis balls; the making of paper bags; the making of boxes or other receptacles or parts thereof made wholly or partially of paper, cardboard, chip, or similar material; the making of brushes; pea picking; feather sorting; the carding, boxing, or packeting of buttons, hooks and eyes, pins, and hair pins; the making of stuffed toys; the making of baskets; and any processes incidental to the above.

The making of electro-plate; files; iron and steel cables and chains, anchors and grapnels; cart gear, locks, latches, and keys. The manufacture of brass, and of any articles or parts of articles of brass; cabinet and furniture making; and any processes incidental to the above.

applies only to the classes of work named in the first part of the footnote on p 681. In emergency it may be exercised by two or more members of the **S.A.** on the advice of the **M.O.H.** The order may be subject to conditions as to disinfection or other precautions.

In case of scarlet fever or smallpox, an employer giving out work or wearing apparel is subject to penalty, apart from any order from the **S.A.** as above, unless he proves that he was not aware of the illness and could not reasonably have been expected to become aware of it.

Industrial poisoning.—"Every medical practitioner attending on or called in to visit a patient whom he believes to be suffering from *lead*, *phosphorus*, *arsenical* or *mercurial* poisoning, or *anthrax*, contracted in a factory or workshop, shall . . . send to the Chief Inspector of Factories, at the Home Office, London, a notice stating the name and full postal address of the patient, and the disease from which, in the opinion of the medical practitioner, the patient is suffering" (s. 73, 1901). By special order of the Home Secretary (January 1st, 1916) *toxic jaundice* has been added to this notifiable list. A fee of 2s. 6d. is allowed. The *employer* must notify such cases to the Inspector of Factories and to the Certifying Surgeon.

Lead poisoning arises in a number of industries, from the materials or appliances used. Owing to more stringent precautions the number of reported cases in the United Kingdom fell from 1,258 in 1899 to 445 in 1914 (28 deaths). For the six years 1909–14 the totals were—

*White lead	188	Printing	167
*Earthenware and china	396	*File-cutting	73
Coachbuilding	481	*Tinning	86
*Smelting of metals	266	Vitreous enamelling	68
*Paints and colours	139	Other	1,045
*Electrical accumulators	205		
Shipbuilding	180	Total	3,294

Those marked * are under special rules or regulations as dangerous trades. The great danger is that of inhalation or swallowing of dust, but there is also risk from carrying unwashed hands to the mouth, from eating or from using tobacco while at work, and in some industries from fumes containing lead. A daily dose of 2 mg. is capable of setting up poisoning. The principal symptoms are gastric pain, anæmia, headache, and paralysis of the forearm. The attack-rate in white lead works is about 25 per 1,000 employed. The chief preventive measures, apart from those directed against dust and fumes (p. 673), are the substitution of materials free from lead or containing it only in an insoluble and comparatively harmless form (and not exceeding 5 per cent. soluble lead), facilities for washing and due use of them, proper arrangement for meals away from work, overalls in dusty processes, periodical medical examination of workers, and exclusion of persons found to be susceptible. Women appear to be more susceptible than men, and the employment of children and even of young persons under 15 is forbidden in certain lead processes, as less attention to precautions can be expected from them.

The figures given above are those for industries as a whole, each including a variety of processes involving very different degrees of risk: thus in pottery processes the incidence is much greater among dippers and ware-cleaners, who handle the glaze before it is fired; and in the processes named much depends upon the nature of the materials handled, the frequency and duration of employment, the conditions of work, including observance of precautions, and upon the age and sex of the workers. These considerations are material in estimating the statistical value of attack-rates or mortality-rates, in all industrial diseases and not merely as regards plumbism. A further necessary consideration is the character of attack, which varies greatly as regards the nature, site, and severity of symptoms, and shades off into constitutional conditions which can hardly be regarded as poisoning or disease, and may only be revealed by large statistics showing greater tendency to more remote affections, such as the kidney disease and gout which are found from mortality returns to be more common among lead-workers than others.

Phosphorus poisoning is now rare, stringent precautions having been imposed in 1898 in the lucifer-match factories in which white (or "yellow") phosphorus was used, and the use of that substance was prohibited from January 1st, 1910, by the White Phosphorus Matches Act of 1908. Its characteristic manifestation is necrosis of the jaw, arising in connexion with carious teeth: it rarely occurs until the employment has been long continued, and there is some reason to suppose that it is dependent upon a constitutional change predisposing to local attack. Substitutes for yellow phosphorus have been found in red phosphorus (a harmless form), sesquisulphide of phosphorus, and other chemicals. The reported attacks from 1900–14 numbered 17.

Arsenical poisoning arises chiefly in connexion with paints and colours and in chemical works, or exceptionally from the evolution of arseniuretted hydrogen in metallurgical processes. In 1909–14 there were reported 34 attacks.

Mercurial poisoning is met with in industries in which mercury or a mercurial salt is used: including the making of thermometers and other scientific instruments, furriers' work (in "carrotting") and chemical works. Formerly it was observed among "water gilders" employed in "silvering" mirrors by means of mercury. In addition to salivation, alimentary disturbances, and cachexia, there are peculiar fine tremors of the hands and arms, with occasional pains in the joints. In 1909–14, 72 attacks were reported.

Anthrax was reported in 342 instances in 1909–14, with 52 deaths. The cases were thus distributed:—

INDUSTRY.	ATTACKS.	DEATHS.
Wool, worsted	191	31
Horsehair, bristles . . .	39	5
Hides, skins.	94	12
Other	18	4

Internal anthrax is generally fatal. Among external cases the pustule is usually (85 per cent.) on the head or neck, but in 12 per cent. on the hand or arm.

The infection in the trades named above is due to materials imported from Eastern countries in which anthrax is rife, e.g. Van mohair, Persian wool, Siberian and Chinese horsehair, Chinese and Persian skins. Dry and dusty materials and processes are especially dangerous, and greasy or moist goods (e.g. salted hides) less so. Where disinfection is impracticable and infected materials are used, the preventive measures turn upon suppression of dust, personal cleanliness, protective garments, and immediate attention to abrasions of the skin, however slight. Early diagnosis, prompt excision of anthrax pustules, and the use of Sclavo's serum are important.

Toxic jaundice may occur in poisoning by trinitrotoluene and tetrachlorethane. *Trinitrotoluene* (T.N.T. or *trotyl*) is a high explosive obtained by nitrating toluene, a benzene compound, soluble in oils, grease, acetone, ether, etc. It is used in powder or molten state and gives off fumes. When mixed with ammonium nitrate 20 per cent. it is known as *ammonal*, and with 40 to 60 per cent. as *amatol*. Like dinitrobenzene, T.N.T. can be absorbed by the skin, or inhaled or swallowed, producing profound changes in the blood. It is excreted by fæces and urine. The characteristics of T.N.T. poisoning are (1) dermatitis of face, hands, and feet; (2) gastritis with abdominal pain, vomiting, and constipation; (3) blood changes, including changes in the leucocytes and erythrocytes, and production of methæmoglobin, with resulting breathlessness and cyanosis; and (4) liver degeneration and toxic jaundice. Preventive methods include reduction of dust and fumes, use of overalls, cleanliness, provision for milk and meals, alternation of work, and medical supervision. *Tetrachlorethane*, as a solvent of acetate of cellulose, is an ingredient of the varnish or "dope" used on aeroplane wings to make them impervious to moisture and air. Inhalation of its vapour produces drowsiness, loss of appetite, constipation, gastric pain, and sometimes jaundice, liver destruction, and coma. Prevention depends on strict control of doping sheds, exhaust ventilation, alternation of work, and medical supervision.

Many other fumes claim victims in industrial processes, including carbon monoxide (blast furnaces, etc.), carbon dioxide, sulphuretted hydrogen, chlorine, nitrous fumes, and benzene derivatives. In the manufacture and use of nitric acid *nitrous fumes* escape and may produce varying degrees of poisoning. Cough, dyspnœa, with vomiting and pneumonic symptoms occur.

Brass-founder's ague, attributed to zinc fumes, is characterized by recurrent attacks, with cold, hot, and sweating stages, differing from those of malaria in not being periodic.

Other provisions of the Factory Act require only brief mention here, and the following summary may suffice:—

Safety.—Dangerous machinery must be fenced or made safe by position. The use of dangerous ways, works, machinery or plant, or of dangerous premises, can be forbidden by a Court. Certain dangerous employments are forbidden to "children" and "young persons," and further limitations of this kind can be imposed by the Certifying Surgeon. Where any manufacture, plant, process, or description of manual labour, is certified by the Home Secretary as dangerous or injurious to health, or dangerous to life or limb, regulations (of general application) or special rules (for particular works) may be made: many such codes are in force.

Accidents which are fatal, or which cause disablement for ordinary work for seven days (or, if caused by power machinery, molten metal, hot liquid, explosion, escape of gas or steam or electricity, such disablement for one whole day), must be registered and reported to the Factory Inspector; and also (except the seven-day accidents above) to the Certifying Surgeon. These obligations arise under an Amending Act (Notice of Accidents Act, 1906) and extend to dock processes and building operations. About 150,000 accidents per year are so reported, and of these rather less than 1 per cent. are fatal.

Age and sex.—Children under 12 may not be employed. Above 12 they may be employed for half-time (if they have attained a certain standard and if the local educational byelaws permit), but must attend school for the other half. In factories and certain workshops they must have a certificate of fitness (as to age and physique) from the Certifying Surgeon, which may be coupled with conditions as to the nature of the employment permitted. "Young persons" are those between 14 and 18 (or between 13 and 14 subject to conditions as to educational certificates), and these are eligible for full-time employment, with certain limitations. Certificates of fitness are required for those under 16 employed in factories and certain workshops. A woman must not be employed within four weeks after giving birth to a child.

Hours and intervals.—The period of employment for women and young persons in *textile factories* is on ordinary days 12 hours (6 to 6 or 7 to 7), less 2-hours intervals, and on Saturday 6 hours (6 to 12 or 7 to 1, with ½ hour interval, or 6 to 12.30, with an hour interval): or a weekly total of 55½ working hours. In *non-textile factories* and in *workshops* it is 12 hours on ordinary days (6 to 6, 7 to 7, or 8 to 8), with 1½ hours intervals, and on Saturdays 8 hours (6 to 2, 7 to 3, or 8 to 4), with ½ hour interval; or a weekly total of 60 hours. In *laundries* additional latitude is allowed.

There is a further limit as to continuous spell of employment, which must not exceed 4½ hours in textile factories and printing, bleaching and dyeing works, or 5 hours in non-textile factories and workshops, without an interval of ½ hour. Certain holidays, amounting to six days in the year, are prescribed. Work on Sundays is prohibited. The hours, intervals, and holidays must be fixed by notice. None of the above provisions apply to men over 18, and certain exceptions are allowed as regards women, young persons, and children in special cases:

e.g. women may be employed "overtime" for 2 hours on not more than 3 days in any week, nor more than 30 days in any 12 months, in certain specified branches; and in others male young persons can be employed at night.

Certain special Orders were issued (1915–16) for relaxing the usual hours for the purpose of war-emergency work.

Welfare work.—In 1915 the Ministry of Munitions and Home Office appointed the Health of Munition Workers Committee, which made various recommendations for safeguarding the personal health and well-being of the munition worker, particularly in regard to industrial fatigue, hours of labour, the provision of canteens, the employment of women and juveniles, the effective ventilation and lighting of factories, sickness and accident, washing facilities, welfare supervision, the protection of eyesight (from eye-strain, heat, fumes, and dust), nightwork, causes of lost time, etc. The Police, Factories, etc. (Miscellaneous Provisions) Act, 1916, s. 7, provides that the Home Secretary may by Order require the occupier to make reasonable provision for preparing, heating, or taking meals, the supply of drinking-water, the supply of protective clothing, ambulance and first-aid arrangements, supply and use of seats in workrooms, facilities for washing, accommodation for clothing, and arrangements for supervision of workers.

The **Alkali, etc., Works Regulation Act, 1906**, applies to a wide variety of chemical and other works, and is administered by Inspectors appointed by the **L.G.B.** It regulates *inter alia* the discharge of acid gases into the atmosphere; thus in alkali works the escaping air or smoke must not contain more than ⅕ gr. of muriatic acid per cub. ft., and in other specified works the acid gases discharged must not exceed the equivalent of 1½ gr. of sulphuric anhydride per cub. ft. The best practicable means must be adopted for preventing the escape of noxious and offensive gases, and rendering them harmless and inoffensive. Acid drainage must not be allowed to mix with alkali waste so as to cause nuisance. The owner may require the **S.A.** to provide and maintain at his expense a drain for carrying the acid waste into the sea or any watercourse into which it can be taken without breach of the law. Alkali waste must not be deposited or discharged without the best practicable and available means being used to prevent nuisance.

On complaint from the **S.A.** or from ten inhabitants that nuisance arises from contravention of the Act, the **L.G.B.** must institute such inquiry and direct such proceedings as they think fit.

Mines are controlled by the Coal Mines Regulation Act, 1887, and the Metalliferous Mines Regulation Act, 1872 (many of the provisions of which are extended to quarries over 20 ft. in depth, by the Quarries Act, 1894), and amending Acts. These Acts are administered by H.M. Inspectors of Mines, but in one or two minor points they give powers under the Public Health Acts to the S.A.

The **Shop Acts, 1892, 1893, 1895, 1904, and 1912,** are administered by the County and Borough Councils. They contain no sanitary provisions, but regulate the hours of employment of young persons under 18, whether wholly in a shop or partly also in a factory or workshop. The total number of hours, including meal hours, must not exceed 74 in any week, and a notice of this limit must be kept affixed in the shop. "Shops" include warehouses and licensed public-houses and refreshment-houses of all kinds. A further Act (Seats for Shop Assistants Act, 1899) requires one seat to be provided for every three female assistants.

The **Workmen's Compensation Act, 1906,** deals with certain industrial diseases as well as accidents. Where (*a*) the Certifying Surgeon (or other practitioner appointed by the Home Secretary for the purpose) certifies that a workman is suffering from a disease named in the table below, and thereby disabled from earning full wages at the

DISEASE. (1)	PROCESSES. (2)
Poisoning (or the sequelæ of such poisoning) by—	
Lead	Any process involving the use of these, or their preparations or compounds.
Mercury	
Phosphorus	
Arsenic	
Carbon bisulphide	
Nitro- and amido-derivatives of benzene and its homologues (trinitrotoluene, aniline, and others)	
Nitrous fumes	Any process in which these gases are evolved.
Nickel carbonyl	
African boxwood (*Gonioma Kamassi*)	Manufacturing articles therefrom.
Anthrax	Handling of wool, hair, bristles, hides, skins.
Chrome ulceration, or its sequelæ	Use of chromic acid, or bichromates, or their preparations.
Ulceration of the skin, or any dermatitis, produced by dust or liquids, or ulceration of the mucous membrane of the nose or mouth produced by dust	——
Ulceration of the nose or mouth produced by dust	
Epitheliomatous cancer or ulceration of the skin or cornea due to tar, pitch, bitumen, mineral oil, or paraffin, or their compounds	Handling or use of pitch tar or tarry compounds.
Epithelioma of the scrotum	Chimney-sweeping.
Glanders	Care of any equine animal suffering from glanders; handling the carcass of such animal.
Compressed-air illness (caisson disease)	Work in compressed air.
Nystagmus	Mining.
"Beat hand" "Beat knee" subcutaneous cellulitis	
"Beat elbow" (acute bursitis)	
Synovitis of wrist-joint and tendon sheaths	
Ankylostomiasis	
Cataract in glass-workers	Processes in the manufacture of glass involving exposure to the glare of molten glass.
Telegraphists' cramp	Use of telegraphic instruments.
Writer's cramp	Any process in manufacture of aircraft.
Dope poisoning	

work on which he was employed, or (*b*) a workman is suspended in pursuance of Regulations or special Rules from his usual employment on account of having contracted such a disease, or (*c*) the death of a workman is caused by such a disease, claim to compensation arises *if the disease can be shown to be due to the nature of the employment*. In certain specified cases (col. 2) this industrial causation is assumed, unless the Certifying Surgeon certifies, or the employer proves, the contrary. Additions to the Act can be made by order of the Home Secretary. Other trades and occupations than those named on p. 689 may also be classified as *dangerous trades* on the ground of the production of dust—metallic, chemical, or organic.

The **Employment of Children Act, 1903,** enables urban **S.A.s** with a population over 20,000 (or, in the case of boroughs over 10,000, and elsewhere, the County Council) to make bye-laws regulating the employment of children under 14 (not under the Factory or Mines Acts) and street trading by persons under 16; it forbids carrying of heavy weights or other injurious occupation, street trading by children under 11, and (in general) work between 9 p.m. and 6 a.m.; but as regards children employed in mines, factories, and workshops, these provisions are administered by Home Office Inspectors only.

Under the **Prevention of Cruelty to Children Act, 1904,** the **S.A.** are charged with the duty of seeing to the observance of the conditions of licences granted by a Court for the employment of children over 10 in public entertainments.

CHAPTER XXI

MILITARY AND NAVAL HYGIENE

THE principles of hygiene which concern communities and residential institutions, and upon which their public health depends, apply equally to the Army and Navy. Military and naval sanitation is, however, "trade" sanitation, that is, it concerns two professions of selected adult men placed for a longer or shorter period under exceptional conditions of confinement in barracks, camps, or ships, and exposed suddenly to exceptional strain and stress, and in various climates. The persons in both these callings are selected lives, thus certain problems of preventive medicine do not arise; on the other hand, they suffer from special incidences of certain diseases, and thus create peculiar problems of their own (e.g. scurvy was formerly a sailors' disease, and tuberculosis and venereal diseases are still prevalent in modern armies), are massed together, are less resistant owing to exposure and fatigue, and frequently have to live temporarily under insanitary conditions.

HYGIENE OF THE ARMY

The health of the soldier must be considered during peace as well as during war, though war time raises special problems. In the South African War approximately 7,000 men were killed by wounds, 14,000 died from disease (principally enteric and dysentery), 400,000 were admitted to hospital, and 72,000 were invalided home. In the present European

War there has been on the Western Front an extraordinary absence of disease, incomparably less, proportionately, than in any previous war. On the Eastern Front there have been the old enemies—typhoid, dysentery, typhus, etc. The exceptional decline in epidemic disease in France and Germany has been due to (*a*) improved feeding and care of the soldier, (*b*) antityphoid inoculation, (*c*) vaccination against smallpox, (*d*) improved hospital and medical service, (*e*) strict sanitation and treatment of water supply, and (*f*) rapid transport.

Sanitary Service.—At the head of the organization is the Director-General of the Army Medical Service, who is assisted by civil and military experts on the Army Medical Advisory Board at the War Office. Under him are various Deputies and Assistants in charge of the Army Medical Department. Next in order come the principal medical officers of commands and divisions, who occupy towards their respective commanders the same position that the Director-General bears to the Army Council. Under them are specialist sanitary officers for each command, division, and unit, the last-named being responsible for sanitation of barracks and camp. In time of war this same arrangement obtains for the field army. The administration of the lines of communication is under an Inspector-General, who has under him a sanitary staff responsible for sanitation of the lines, subdivided into "sanitary districts," each having a sanitary "section" forming the nucleus of a sanitary establishment and responsible for the "Sanitary Squads." The duties of the squad are (*a*) to execute skilled sanitary work in connexion with disinfection, water supply and conservancy, and (*b*) to act as sanitary police. The duties of the "district" sanitary officer, on the other hand, are analogous to those of a M.O.H., and the officer at the base acts like a Port Sanitary Authority and isolation hospital superintendent. In addition to the above organization a Sanitary Section is formed on mobilization for general supervision (undertaken by engineering, veterinary, and medical officers). A Sanitary Section consists of an officer and 25 men. It is important that, when military units are camped in this country, the civil and military Sanitary Services should co-operate to secure efficient supervision of camp sanitation (water supply, refuse disposal, drainage and conservancy, hutments, food storage, etc.), the control of infectious diseases (internotification, isolation, disinfection, protective inoculation), billeting (40 sq. ft. and 400 cub. ft. per man), and any matters affecting health and sanitation of the area.*

Selection of soldiers.—The British Army was formerly enlisted on the voluntary system, but conscription was introduced in 1916. Recruits must be of a certain height (5 ft. 3 in. to 5 ft. 8 in.) and chest girth (33½ in. and expansion range of 2 in.). Before enlistment is complete each recruit is examined by a medical officer under the Medical Regulations for mental condition, absence of infirmity (including hernia and varicocele), condition of heart, lungs, joints, feet, sight, hearing, etc. Before the War, of the recruits examined in the United Kingdom, 30 per cent. were rejected as unfit for the Army. About 1 per cent. further were rejected as unfit within three months of enlistment. The chief causes of rejection are loss and decay of teeth (18 per cent. of rejections), under chest measurement, diseases of the heart, defective vision, varicose veins, etc.

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* TABLE OF INFANTRY MEASURE

1,019 men = 1 battalion. 4 battalions = 1 brigade.
8 brigades = 1 division.

A Division consists, therefore, of about 12,000 infantry. The accompanying units, necessary for its efficiency, are collectively named "Divisional Troops," as opposed to the Infantry Battalions. They include three batteries of Artillery with Ammunition Column and one squadron of Cavalry, besides Engineers, Army Service Corps (Food Supply and Transport), Ordnance (tents and kit), and three Field Ambulances with six ambulance wagons and one tent-division apiece, the latter representing the once independent field hospital of the South African War.

The medical arrangements, preventive and curative, are all under the direction of the Administrative Medical Officer, a Territorial colonel, who is directly responsible for them to the General Officer Commanding. The Administrative Medical Officer is advised by his staff officer, a retired or seconded captain or major of the Royal Army Medical Corps, who carries out all the routine duties throughout the year in the name of the Administrative Medical Officer. For sanitation he is advised by a Sanitary Officer, a lieutenant-colonel or major of the Territorial Royal Army Medical Corps. But the medical work of each unit, for which the commanding officer is in each case held responsible, both curative and preventive, is in the hands of the medical officer of that unit, or, in his absence, of the quartermaster. In 1915–17 there was extraordinary development in the medical and ambulance (motor) service.

Barracks.—Site, situation, and general sanitation must be judged as for other residential institutions. The dimensions of the barrack room are —length 60 ft., breadth 20 ft., and height 12 ft. Each of the 24 men has therefore 600 cub. ft. of air. Between two barrack rooms is the central staircase, and at each of the ends is an ablution room, one basin and urinal being provided for every four men and 15 gallons of water for each man. In every case a bath is also fixed. Ventilation is obtained by the natural system. Five sanitary conveniences should be provided for every 100 men. In India barracks are further provided with punkahs, plunge baths, and dry earth closets; in the plains the regulations sanction 1,800 cub. ft. of space per man. Disease rarely originates in the barracks; it is introduced from outside, and spreads in proportion to the degree of overcrowding existing. Delorme claims that the space between barrack sleeping-cots is the most important requirement in barrack hygiene. Cubic space in the dormitory must never be sacrificed to cubic space in the dining and recreation rooms.

Camps should be compact and, as far as possible, fixed in salubrious positions. High ground or a hill-side, on grass if possible, is the best site.

River beds, ravines, and depressions of ground, as well as tilled or made ground, are bad sites. Accommodation is provided by bell or circular tents (15 healthy or 4 sick men), or hutments, which are preferable in winter. The chief sanitary points requiring attention in selecting a camp site are (*a*) suitability of soil, (*b*) adequate water-supply, (*c*) conservancy arrangements. The soil should be sand or gravel, with a pervious, absorptive, sloping surface. The quantity of water required daily is usually estimated at 5 gallons per man in standing camp and 10 gallons per horse. Less than 1 gallon per man daily is privation. Water in camp may be obtained from a municipal supply, river, lake, spring, or well, or it may be necessary to bore (Norton's pump, *see* p. 46). A water-supply staff must be appointed, responsible for collection and purification (which may be secured by sedimentation, precipitation by 1 grain of alum per gallon, or filtration). Filtration of water in camp may be accomplished by means of (*a*) a blanket or sheet of cloth, (*b*) double-barrel filter, or (*c*) domestic filter (Berkefeld or Pasteur-Chamberland in England, Germany, and France, Darnell in America, Ishiji in Japan). Where practicable and necessary, a sterilizer may be used (usually pasteurization at 80° C. is found sufficient). Colonel Melville advocates, for troops on the move, filter carts, or filters carried by pack or human transport; for stationary units and standing camps, some form of heat; for small detached bodies of intelligent men for short periods, chemical treatment (permanganate of potash, sulphate of soda in a strength of 15 gr. to the pint, etc.). Conservancy includes latrines and refuse disposal.

Latrines in camp may suitably take the form of a water-carriage system, a pail system, or trenches. Trenches should be short, 3 ft. long, 1 ft. wide at the top, and 2 ft. deep, broader at the bottom (15 in.) than at the top. The upper edge of the trench may be rebated, leaving a ledge 6 in. broad and 4 in. deep on each side of the trench. The distance between the trenches should be 2½–3 ft. and one trench is sufficient for 20 men. One set of such trenches can be used for four days, and if a camp is to remain in one place for more than a fortnight a pail system must be instituted with proper wooden latrines. Where trenches are used all excreta should be covered immediately, and trowels or scoops must be provided. Screening is necessary. One form of camp urinal—that described by Captain Tilbury Brown—consists of a 4-ft.-square pit into which run two trenches, 12 ft. long and 2 ft. wide, with a fall of 1 in. per foot. The pit may be one-third filled with old tins and clinker from the camp destructor and then filled up with stones, gravel, and dry earth, and the urine, if conducted to the bottom of the pit, must filter upwards, which allows for oxidation. Portable tubs or buckets one-quarter full of creosol (1–360) may be used at night (6 per cent. basis), and the contents ultimately placed in a special pit. When-

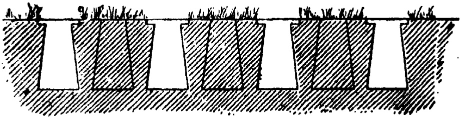

Fig. 74.—Army latrines, cross section.

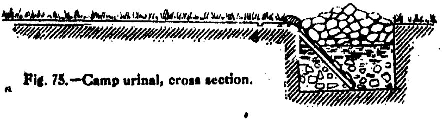

Fig. 75.—Camp urinal, cross section.

ever a camp is occupied as a permanency, pail earth closets must be used (*see* p. 225). Latrines of whatever kind should be 100 yards from the tents or huts (leeward preferably).

Refuse disposal is concerned with human and horse excreta. (*a*) Removal of pails to earth pit or destructor must be effectually provided for, and regulations are issued to sanitary squads. Urine and sullage may be conveyed by drainage to a disposal area (with sedimentation tank when necessary). Trenches are filled in with earth. (*b*) Horse manure and stable refuse must be removed frequently to prevent breeding of flies. Its destruction may be obtained by contract with farmers, by burying, or by use of a destructor. Horse lines should be frequently changed and freely sprayed with paraffin or creosol, after scraping. Destructors for human excreta are of two types, the Unit (Horsfall) serving 1,000 men, and the Central (Meldrum) for 5,000–8,000 men, the latter necessitating cartage. For horse manure and other refuse a specially constructed incinerator is often used. Garbage and kitchen refuse should be buried or burnt. Camp cleanliness is always of the greatest importance, for even among healthy troops a few men may be typhoid-carriers, etc. Creosol, solar oil, or kerosene should be used as disinfectants.

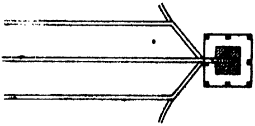

Fig. 76.—Camp urinal, plan.

Ablution and bathing.—Ablution-benches should be fixed, and inexpensive shower-baths (an upright water-standard with cross-arm and rose discharge over concrete gutter with wooden grating), "sump" holes for waste water, kitchen discharges, and urine, are required.

Kitchen arrangements.—Cook-houses, larders, and mess tents are necessary. The sanitary problems created are chiefly the prevention of fouling of soil or floor, disposal of waste and refuse, and preservation of food (which may readily become contaminated in storage, preparation, distribution, or consumption).

The efficiency of a conservancy system may be judged largely by the presence or absence of flies. Spraying with crude carbolic solution or solution of creosol or formalin (1–39), or the use of "oil-resin fly wires," or of quicklime, combined with cleanliness and frequent removal of all refuse and horse manure (the breeding-places of flies), are the best preventive methods. If removal is impracticable, "close packing" of manure is effective. For disinfection in camp, carbolic, chloride of lime, and paraffin oil are useful. The sites of latrines should be marked when the camp is moved.

General hygiene.—The health of the field army depends in large degree upon the personal hygiene of the rank and file, and this in turn is dependent upon sufficiency and suitability of food and clothing, cleanliness of the person, moderation or abstinence as regards alcohol, avoidance of sunstroke by day and chill at night, and the care of the feet. Rations and emergency rations, marching and water and refuse discipline require careful supervision. The frequent and careful washing, and the subsequent careful drying, of the feet is a matter of the first importance (0·5 per cent. formaldehyde or weak permanganate may be used for hyperidrosis). Foot powder may be necessary: 3 parts of salicylic acid, 10 of starch, and 87 of talc is a mixture used in the German army; and swabbing with a 10-per-cent. solution of chromic acid in the

French army. Well-made knitted woollen socks and properly fitting boots are, of course, necessary. The commonest causes of men falling out on the march are (*a*) intestinal and stomach troubles, (*b*) faintness from starting on empty stomach, (*c*) sore feet, and (*d*) heat. Drinking-water may require the addition of bleaching-powder solution (3–5 drops per water-bottle, or 2 grm. powder to 1 pint of water), alum (5 gr. to 1 gall. of water), or potassium bisulphate (15 gr. to pint). The Horrocks water-testing cabinet is a necessary addition to the equipment.

Preventive methods.—The principles of the prevention of disease in the Army are, broadly, the same as in other communities, namely, a non-infectious environment, early recognition of the disease on occurrence, isolation or segregation of the infectious sick, and disinfection. The chief diseases to be considered are tuberculosis, enteric fever, dysentery, malaria, heat-stroke, ophthalmia, measles, and venereal disease. In the European War (1917), shock, neurasthenia, trench fever, paratyphoid, and cerebro-spinal fever have prevailed. Of the infectious diseases, the intestinal (enteric, dysentery) are the most serious, and of the tropical diseases, malaria. For the prevention of enteric, the segregation of the "carrier" case, the reduction of infection by flies contaminating food, and the effective control of the water supply and the conservancy system are the essential points. In cholera it is usually sufficient to concentrate on the water supply. The preventive methods for tuberculosis and malaria are those practised in civil communities. The other infectious diseases which call for action are smallpox, measles, and scarlet fever. Vaccination of every man in the unit against smallpox, and anti-typhoid inoculation, are essential. Heat-stroke is avoidable by suitable headgear, marching in "open order," avoidance of undue fatigue, and abstinence from alcohol. Ophthalmia in its various forms is preventable by ample air-space and ventilation, cleanliness, protection of the eyes from dust and glare, and early segregation of the sick.

Military hospitals.—Hospital construction for military purposes is, of course, generally speaking, the same as for civil. The regulations allow 1,200 cub. ft. for each man, in tropical climates 1,500 ft., and in India 1,600 ft. (in the hills) to 2,400 ft. (in the plains). Military hospitals are classified for districts and commands and for the field army. The former include general, station, and lunatic hospitals, and special hospitals on troopships, and for soldiers' wives and children; the latter include general hospitals, hospitals on the lines of communication, field hospitals, and hospital ships. The field hospital system consists of (*a*) collecting stations near the fighting line but under shelter, (*b*) the dressing stations out of range of fire, (*c*) the field hospital (tents), and (*d*) the general hospital at the base (huts).

Mortality statistics.—The chief causes of disease-mortality in modern armies are phthisis, heart disease, diseases of the nervous system, lung disease, and fevers (including rheumatic). The ravages of disease in the field, either fatal or disabling, are mainly due to injuries, venereal disease, enteric, diarrhœa, and dysentery, malaria, infectious diseases, and minor septic diseases. Caries of the teeth, and sore feet, must also be added as disabling conditions. Typhus[*] and scurvy[†] have disappeared as serious contributors. The death-rate for British troops previously to the War was about 2–4 per 1,000 at home, 3–8 per 1,000 in the colonies, and 5–18 in India. The "constantly sick" rate was 28·0 per 1,000. Within a decade (1899-1908) the effective strength of our Army, as indicated by the fall in "constantly sick" rates, was raised by 5,776 men, and the wastage through deaths and invalidity reduced by about 3,000 men per annum. This result is attributed to (*a*) changes in the medical administration, (*b*) improved methods in the treatment of disease, (*c*) improved sanitation, and (*d*) greater care and uniformity in recruiting.

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[*] It is officially stated that in the Bavarian army, in 1812, 25,000 out of 28,000 men died of typhus, and after Plevna 60,000 out of a strength of 120,000 of the Russian army.

[†] In the Crimean War the Turkish army was nearly destroyed by scurvy, and there were 40,000 cases in the allied English and French armies.

HYGIENE OF THE NAVY

The chief problem of hygiene at sea originates in the limitation of accommodation on board ship—cubic capacity, cleanliness, ventilation, spread of infectious disease, and dietary are all involved. There is still much room for improvement in these matters, particularly in the merchant service. The Merchant Shipping Act, 1906, enlarged the minimum cubic space for a merchant seaman, in ships laid down after 1906, from 72 to 120 cub. ft. per head (for sleeping). For a man-of-war the Admiralty allowance is 200 cub. ft., with a fan supply of 3,000 cub. ft. of air per hour per man. Ventilation at sea is generally secured by perflation, advantage being taken both of wind and of the air-currents produced by the onward course of the ship. The air is collected by cowls, which direct it through shafts, or it is sent below by wind-sails or, in calm weather, by wind-scoops. Some of the largest passenger steamships are now heated by hot pure air from thermo tanks on the top deck, supplying air to all parts of the ships, from which used air is artificially extracted. The Sirocco fan, the Utley port-hole ventilator, and the plenum system (with or without a vacuum system) are also used. Special methods of ventilation are necessary for engine-rooms, stokeholds, and bath-rooms; also, of course, for submarines. Lighting, heating, drainage, mess-rooms, lavatories, and water-closets need consideration and supervision, and ample provision must be made for water supply, hospital isolation, and disinfection.

In the British Navy previously to the War (1912) the death-rate per 1,000 was 3·3 from all causes, and 2·04 per 1,000 from diseases alone. In 1858 these two death-rates were 25·8 and 22·0 respectively. The chief causes of death are: general injuries and accident (casualties, burns, poisoning, shock, explosions, etc.), pneumonia, disease of the circulatory system, enteric and other fevers, and tuberculosis. In 1909, out of 72,540 cases of disease or injury, 15,046 were attributed to injury, 13,474 to venereal diseases (including gonorrhœa), 11,691 to diseases of the digestive system, 8,268 to diseases of the skin, and 7,762 to respiratory diseases. The average number of men sick daily in the whole Fleet in 1914 was 20·3 per 1,000, as compared with 229 in 1782 and 64 in 1806. The incidence of sickness differs according to the three parts of the Navy: (*a*) shore depôts and training establishments; (*b*) the Service afloat; and (*c*) the Royal Naval Division and Marines serving on land. The great improvement is due not only to increase of cubic space and better ventilation, but to cleanliness, personal hygiene, and improved sanitation, the use of lime-juice, and the earlier recognition and isolation of cases of infectious disease followed by disinfection. At the present time (1917) much is also due to the comparative isolation of the fleets, and the strict quarantine arrangements. Owing to the immense reduction in the length of voyages the dietary is more liberal and varied. Scurvy (*see* p. 106) has almost disappeared except in special circumstances. Disinfection on board ship is usually carried out by washing with suitable disinfectant (e.g. liquid sulphurous acid) and fumigating with sulphur (1 lb. to every 500 ft.). In vessels carrying inflammable cargoes, liquid sulphur dioxide may be used. Water-tanks may be treated with permanganate of potash, or preferably with steam. Bilges are disinfected by pouring in strong disinfectant solution, allowing the water to enter, and then pumping into the sea. Rats are best killed by pumping in a lethal gas (carbon monoxide, carbon dioxide, sulphur dioxide, etc.). Hospital ships do not now accompany fleets in action, but serve as "marine ambulances," base, clearing, and isolation hospitals.

Port Sanitary Authorities.—Reference is made elsewhere to the various duties now devolving upon Port Sanitary Authorities, but it may be convenient to summarize them here. The four most important are—(1) the supervision of all conditions affecting the health of persons on shipboard; (2) the prevention of the introduction of infective disease through the ports, and the removal to hospital of cases of dangerous infectious disease on board ship; (3) the control of importation of foreign meat and other foods from a health point of view; and (4) the sanitation of ports. The general and particular principles of hygiene dealt with in this book apply in these as in similar matters in ordinary sanitary areas, but certain special arrangements have been made to which cross-reference is desirable.

Cases of sickness among sailors and soldiers.—Section 5 (*b*) of the Local Government (Emergency Provisions) Act, 1916, provides that the **M.O.H.** of a local Authority shall receive notifications of all cases of infectious diseases arising in barracks, camps, etc., in the occupation of His Majesty's Forces. The Act came into force on May 17th, 1916. Before this date the duty of notifying cases of infectious diseases to the **M.O.H.** did not apply in respect of persons living in any building, etc., belonging to the Crown.

CHAPTER XXII

BYE-LAWS AND REGULATIONS

Bye-laws, having the force of law, may be made by Sanitary Authorities for the better government of their districts, but only in respect of certain matters, and under certain conditions, expressly stated in the Acts of Parliament. They are designed to supplement, not to summarize, vary, or supersede, the express provisions of the statute law. It is, of course, quite open to any **S.A.** to append to their bye-laws a statement or summary of the requirements of the statute law bearing upon the same matters. In some cases this course is advised by the **L.G.B.** Bye-laws must be reasonable, and must not in any particular be repugnant to the provisions of the general law. They have (as a rule) no force until approved by the **L.G.B.** Any bye-law may be altered or repealed by a subsequent bye-law. In framing bye-laws, a **S.A.** should impose reasonable penalties, not exceeding £5 for each offence; and in the event of a continuing offence, a further penalty not exceeding £2 per day.

Urban authorities are empowered to make bye-laws as follows:—

1. **Private scavenging.**—For imposing upon occupiers the duty of cleansing pavements and footways, of removing house-refuse, and of cleansing earth-closets, ashpits, privies, and cesspools. Such bye-laws are only to be made if the **S.A.** do not undertake or contract for these matters * (Public Health Act, 1875, s. 44).

2. **Prevention of nuisances.**—For the prevention

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* But see the Public Health Acts Amendment Act, 1890, p. 608.

of nuisances arising from snow, filth, dust, ashes, and rubbish. For the prevention of the keeping of animals on any premises so as to be injurious to health (Public Health Act, 1875, s. 44).

3. **Common lodging-houses.**—For regulating the number of lodgers and the separation of the sexes; for promoting cleanliness and ventilation; for giving notice and taking precautions in case of infectious disease; and for the general well-ordering of such houses (Public Health Act, 1875, s. 80).

4. **Houses let in lodgings.**—For regulating the number of persons and separation of the sexes in a house or part of a house let in lodgings or occupied by members of more than one family; for the registration and inspection of such houses; for drainage, privy accommodation, cleanliness, and ventilation; for cleansing and whitewashing at fixed times; for paving of yards; and for giving notice and taking precautions in case of infectious disease[*] (Public Health Act, 1875, s. 90). The Merchant Shipping (Fishing Boats) Act of 1883 gives power to the **S.A.** to make bye-laws for the regulation of *seamen's lodging-houses.*

5. **Hop-pickers.**—For securing the decent lodging and accommodation of persons engaged in picking hops (Public Health Act, s. 314).

6. **Fruit-pickers.**—For securing the decent lodging and accommodation of persons engaged in picking fruit and vegetables (Public Health [Fruit-pickers] Act, 1882).

7. **Tents and vans.**—For promoting cleanliness in, and habitable condition of, tents, vans, sheds, and similar structures used for human habitation; for pre-

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[*] The **M.O.H.** must on request inspect any house wholly let in tenements at rents not exceeding 7s. 6d. weekly, and (if satisfied) certify that the accommodation and sanitary arrangements are suitable. The effect is to exempt from Inhabited House Duty. The **S.A.** may appoint another practitioner, qualified to act as **M.O.H.**, to give such certificate (Customs and Inland Revenue Act 1890).

venting the spread of infectious disease by the occupants thereof; and generally for the prevention of nuisances in connexion with the same (Housing of the Working Classes Act, 1885).

8. **New streets and buildings.**—With respect to the level, width, construction, and sewerage of new streets; with respect to the structure of walls, foundations, roofs, and chimneys of new buildings, for securing stability and for the prevention of fires, and for purposes of health; with respect to ventilation and sufficiency of air-space about buildings; with respect to drainage, closets, ashpits, and cesspools; with respect to the depositing of plans and sections of proposed new streets and buildings; with respect to the power of the Authority to remove, alter, or pull down any work which has been begun or done in contravention of the bye-laws; and with respect to the closure of buildings unfit for habitation (Public Health Act, 1875, s. 157).

9. **Mortuaries.**—For the regulation of charges and management of public mortuaries (s. 141).

10. **Cemeteries.**—For the regulation of charges and management (Public Health [Interments] Act, 1879).

11. **Slaughter-houses.**—For the licensing, registering, and inspection of slaughter-houses and knackers' yards; for preventing cruelty therein; for cleanliness and daily removal of filth; and for providing a supply of water (Public Health Act, 1875, s. 169).

12. **Offensive trades.**—For preventing or diminishing the noxious or injurious effects of any offensive trades (Public Health Act, 1875, s. 113).

13. **Markets and fairs.**—For preventing nuisances in markets and fairs; for inspection of slaughter-houses, and daily removal of refuse therefrom; for preventing the sale or exposure for sale of unwholesome provisions; and for many other purposes

(Public Health Act, 1875, s. 167, and Public Health Act, 1908).

14. **Open spaces.**—For the regulation of public walks and pleasure grounds (Public Health Act, s. 164). For the regulation of any open space, churchyard, cemetery, or burial ground over which the **S.A.** has control (Open Spaces Act, 1887).

15. The Municipal Corporations Act, 1882, s. 23, gives power to the Council of a borough to make bye-laws for the prevention and suppression of **nuisances** not already punishable in a summary manner by virtue of any Act in force throughout the borough. County Councils have similar power under the 16th section of the Local Government Act, 1888.

16. For the regulation of **buildings provided under the Housing of the Working Classes Acts.**

17. By adopting certain portions of the Public Health Acts Amendment Act, the **S.A.** may make bye-laws as to **public conveniences** provided by them; and also additional bye-laws as to **new (and old) buildings, removal of house refuse, and prevention of nuisances** (p. 603).

18. For **means of escape from fire,** in factories and workshops (Factory and Workshop Act, 1901, s. 15).

Rural Authorities have similar powers in respect of the following:—

Private scavenging (1, 17).
Common lodging-houses (3).
Houses let in lodgings, and seamen's lodging-houses (4).
Hop-pickers (5).
Fruit-pickers (6).
Tents and vans (7).
Mortuaries (9).
Means of escape from fire, in factories and workshops (18).

And also under the Housing of the Working Classes Acts (16). By adopting portions of the Public Health Acts Amendment Act, they can make certain bye-laws as to new (and old) buildings (8, 17). The **L.G.B.** may confer upon them any other powers as to bye-laws which the Public Health Acts give to Urban Authorities (Public Health Act, 1875, s. 276).

Bye-laws as to common lodging-houses must be made by every **S.A.**, and as to slaughter-houses by every urban **S.A.**; the rest are optional.

Any **S.A.** may make regulations under the Dairies Order (*see* p. 630).

A **S.A.** may make regulations (to be approved by the **L.G.B.**) for the removal to hospital, and detention in hospital as long as necessary, of persons brought within their district by ship or boat, and infected with any dangerous infectious disorder (Public Health Act, s. 125). They may also make regulations for the management of places provided by them for post-mortem examinations ordered by a coroner.

Model bye-laws have been prepared by the **L.G.B.** in respect of certain of the matters upon which Sanitary Authorities have power to frame bye-laws. The following dealing with health matters have been issued up to the present time:—

Private scavenging.
Prevention of nuisances.
Common lodging-houses.
New streets and buildings.
Markets.
Slaughter-houses.
Baths and wash-houses.
Tents, vans, sheds, etc.
Houses let in lodgings.
Cemeteries. Mortuaries.
Offensive trades.
Hop-pickers.
Means of escape from fire, in factories and workshops.
Prevention of waste of water.

These Models* are now very generally adopted, with occasional slight modifications, by Sanitary Authorities seeking to frame bye-laws. The following summary includes only those which have a more direct bearing upon sanitary matters:—

1. **Private scavenging.**†—The occupier of any

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* The semi-official *Annotated Model Bye-laws* (Knight and Co.) contains many important notes, additions, and illustrations.

† Applicable to districts where the S.A. do not undertake these duties.

premises must cleanse the footways and pavements adjoining his premises *daily* except Sunday. He must remove the house refuse *once a week*, and excreta at intervals not exceeding the following maximum limits :—

	Must be cleansed at least—
Earth-closets, with fixed receptacle	once in three months.
,, ,, movable ,,	once a week.
Privies, whether the receptacles are fixed or movable	once a week.
Ashpits, whether receiving excreta or not	once a week.
Cesspools	once in three months.

2. **Prevention of nuisances.**—(*a*) *Clearing away snow.*—The occupier of any premises must clear away snow from the footways and pavements adjoining his premises, as soon as possible after it ceases to fall.

(*b*) *Scavenging.*—The refuse from any premises shall only be removed in a suitable covered receptacle or carriage ; and if from premises within 20 yards of any dwelling, public building, or place of business only between [7.0 and 9.30 a.m.] from November to February, and between [6.0 and 8.30 a.m.] from March to October. The occupier of any premises must cause all refuse to be placed in a movable receptacle, and generally facilitate the work of collection. Refuse must not be deposited upon any road, and any refuse accidentally falling upon a road must be immediately gathered up and the place cleansed.

(*c*) *Deposit of nightsoil and other refuse.*—No load of filth must be deposited for more than [24] hours within [100] yards of any street, dwelling, public building, or place of business. Nightsoil deposited for agricultural purposes upon land within [100] yards of a street, dwelling, etc., and not deodorized, must at once be dug or ploughed into the ground.

(*d*) *Keeping of animals.*—Swine must not be kept within [100] ft. of any dwelling, nor cattle where they may pollute water likely to be used for drinking, domestic, or dairy purposes, or for manufacturing drinks. The same prohibitions apply to storage of dung. Premises wherein are kept any swine, cattle, horses, etc., must be provided with proper receptacles for manure, and with efficient drainage; the receptacle must be water-tight, covered, and entirely above the level of the ground, and it must be cleansed at least once a week; the drain must be properly constructed and kept in order at all times, so as to convey all liquid filth to a sewer, cesspool, or other suitable receptacle.

3. **Common lodging-houses.** (*a*) *Number of lodgers.*—The **S.A.** may specify by notice in writing the maximum number of lodgers to be accommodated in each room, and the keeper must not allow this number to be exceeded; notice stating the maximum number allowed must be exhibited in each room.* The **S.A.** may vary the number from time to time by further notice.

(*b*) *Separation of sexes.*—In general, no person above 10 years of age must occupy the same sleeping-room as persons of the opposite sex, but rooms may be set apart for the sole use of married couples, to the exclusion of other persons over 10 years of age, on condition that every bed is screened off. No bed must be occupied by more than one male above 10 years of age.

(*c*) *Cleanliness of premises.*—The yards, etc., must be kept clean and in good order; all floors swept daily and washed once a week; all windows, painted surfaces, and fittings of wood, stone, or metal, kept clean.

(*d*) *Closets* must be kept clean and in good and efficient order.

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* It is usual to require at least 300 cub. ft. of air-space per head, but to count two children as one adult.

(*e*) *Ashpits* must be kept clean and in good order. No filth or wet refuse must be thrown into ashpits designed for dry refuse only.

(*f*) *Management of sleeping-rooms.*—The windows must be opened fully for an hour in the morning, and an hour in the afternoon, except in case of stress of weather or occupation of the room by a sick person, or other sufficient cause. Beds must be stripped of clothes and exposed freely to the air for an hour each day, and must not be reoccupied within eight hours after being vacated. All refuse and slops must be removed every day before 10 a.m., and all utensils cleansed daily. Every sleeping-room must be provided with sufficient bedsteads, beds, bedclothes, and utensils, for the use of the maximum number of lodgers to be received therein.

(*g*) *Facilities for washing.*—A sufficient supply of suitable basins, water, and towels must be provided for the use of lodgers; and must be kept clean and renewed as required.

(*h*) *Precautions in respect of infectious diseases.*—If the keeper finds that any lodger is suffering from an infectious disease, he must at once take all necessary precautions. No person, except a relative or attendant, must occupy the same room as the sick person. If the patient is removed to hospital by the **S.A.** the keeper must afford all facilities for removal and must adopt all precautions directed by the **M.O.H.**

He must, if required by the **M.O.H.** to do so, temporarily cease to receive lodgers into any infected room. At the end of the case by removal, recovery, or death, the keeper must at once give notice to the **M.O.H.** and must cleanse and disinfect every part of the infected rooms and their contents, and in doing so must comply with all instructions of the **M.O.H.** When the cleansing and disinfection are completed, he must give notice thereof to the **M.O.H.**, and must not receive any lodger into the rooms in question until two days after such notice has been given.

(*i*) *A copy of the bye-laws* in force with respect to Common Lodging-Houses, supplied by the **S.A.**, must be exhibited in some conspicuous place in the house, and must not be concealed, altered, obliterated, or injured.

As some of the most important regulations regarding common lodging-houses are contained in the Public Health Act, and are therefore omitted in the bye-laws, it is desirable that a statement of the provisions of ss. 75 to 89 of the Public Health Act should accompany the copy of bye-laws supplied to each common lodging-house.

As regards the question of the suitability of any particular premises or particular rooms for registration, a Memorandum, issued by the **L.G.B.**, points out that a common lodging-house should, in the first place, possess the conditions of wholesomeness needed for houses in general, and secondly, that it should have arrangements fitting it for the special purpose of receiving a given number of lodgers. Inside walls should not be papered. Every registered room should have special means of ventilation (by chimney if possible), and a window opening freely and directly upon the outer air. There should be kitchen and day-room accommodation apart from the bedrooms. Rooms partially underground should not be registered as sleeping-rooms. There should be a supply of pure water allowing at least 10 gallons per head per day for the maximum number of inmates, and one closet for every twenty registered lodgers. Wherever practicable, there should be a separate place for washing, not in the bedrooms, with fixed basins and trapped and disconnected waste-pipes.

4. New streets and buildings. (*a*) *Streets.*—No new street must be less than 36 ft. wide, if it exceeds 100 ft. in length or is intended to be a carriage road; nor less than 24 ft. in any case. One end at least must be quite open.

(*b*) *Sites.*—No buildings must be erected upon soil polluted with animal or vegetable matter. Sites in low and damp situations, near rivers or in excavations, must be elevated artificially. The site of a new house must be entirely asphalted or covered with 6 in. of concrete.

(*c*) *Walls* of all new buildings must be constructed of good bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together with good mortar compounded of good lime and clean sharp sand or other suitable material, or with good cement, or with good cement mixed with clean sharp sand. Every wall must have a proper damp-course of durable and impervious material beneath the level of the lowest timbers and at least 6 in. above the ground. If the ground is to be in contact with a wall above the level of the floor of the lowest storey, that wall must be made double, with a cavity 2½ in. wide extending from the base of the wall to 6 in. above the surface of the adjoining ground; and damp-courses must be inserted both at the base of the wall and at the level of the top of the cavity. Walls of new houses must be at least 9 in. thick, increasing according to a prescribed scale when the height is greater than 25 ft., or the length greater than 30 ft. Party-walls must be carried up at least 15 in. above the roof, the distance to be measured at right angles to the slope of the roof. The **L.G.B.** permit certain modifications in the bye-laws for buildings in rural districts. (*Circular*, 5th Jan., 1906.)

(*d*) *Roofs* must be made of incombustible materials, and provided with gutters leading to rain-pipes.

(*e*) *Open space.*—A new house must have along its whole frontage an open space measuring at least

24 ft. to the boundary of any land or premises immediately opposite or to the opposite side of the street. In the rear there must be an open space exclusively belonging to the house, at least 150 sq. ft. in area, and free from any erection above the ground-level except a closet and an ashpit; the open space must extend along the entire width of the house, and must measure in no case less than 10 ft. from every part of the back wall of the house; if the house is 15 ft. high, the distance must be 15 ft.; if 25 ft., then 20 ft.; and if 35 ft. or more, then 25 ft. at least.

(*f*) *Ventilation beneath floors.*—If the floor of the lowest storey is boarded, there must be a clear space of at least 3 in. between the boards and the impervious covering of the site, and the space must be ventilated.

(*g*) *Windows* opening directly into the external air must be provided in every habitable room. The window area must be at least one-tenth of the floor area; at least half of each window must be made to open, and it must open at the top.

(*h*) *Ventilation.* — Every habitable room must either have a fire-place and chimney, or a special ventilating aperture or air-shaft with an unobstructed sectional area of at least 100 sq. in. Every new building must be provided with adequate means of ventilation.*

(*i*) *Drainage.*—Damp sites must be drained by earthenware field pipes properly laid to a suitable outfall, but not directly communicating with any sewer or cesspool or drain containing sewage. Rain-pipes must be provided to carry away all water falling on the roof without causing dampness of the walls or foundations. The level of the lowest storey must be such as to allow of the construction of a drain sufficient for the drainage of the building communicating with a sewer at a point above the centre of the sewer. All drains for sewage must be made of impervious pipes 4 in. or more in internal diameter, laid with a proper fall in a bed of concrete, and with water-tight joints. Every drain inlet not intended for ventilation must be trapped. No drain conveying sewage must pass under a building unless no other mode of construction is practicable; in that case it must be laid in a direct line for the whole distance beneath the house, and must be embedded in and covered with concrete 6 in. thick all round, and must be laid at a depth below the surface at least equal to its diameter, and, lastly, must be ventilated at each end of the portion beneath the building. The main drain must be trapped at a point within the curtilage, but as distant as practicable from the building. Branch drains must join other drains obliquely in the direction of flow.

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* The semi-official Model Bye-laws under the Public Health Acts Amendment Act prescribe a minimum height of 9 ft. in every part, except in attics used as bedrooms, when a minimum height of 5 ft. is permitted, if in two-thirds of the area the height is not less than 9 ft.

(*j*) *Ventilation of drains.*—There must be at least two untrapped ventilating openings into the drains, according to one of the following alternative arrangements: (1) One opening consists of a shaft or disconnecting chamber opening at or near the ground level, and situated as close as possible to the trap specified above, but on the house side of it; the other opening is a pipe or shaft carried from a point as far distant as possible from the said trap (i.e. as near as possible to the head of the drain) vertically upwards in such manner and to such height (in no case less than 10 ft.) as to prevent any escape of foul air into any building; but (2) if more convenient, the relative positions of these openings may be reversed, the shaft being placed near the trap, and the opening at the ground-level at the head of the drain. The ground-level opening must have a grating, with apertures equal in total area to the sectional area of the drain. The pipe or shaft at the other end of the drain (whether used as a soil-pipe or not) is required to have a sectional area equal to that of the drain, and in no case less than 4 in.; and bends and angles are to be avoided as far as practicable.

(*k*) *Disconnection of drains from house.* — No drain inlet is permitted within a building except the inlet necessary for a water-closet. Every soil-pipe must be at least 4 in. in diameter, must be placed outside the building, and must be continued upwards in full diameter, without bends or angles (except where unavoidable), to such a height and such a point as to afford a safe outlet for sewer air. There must be no trap between the soil-pipe and the drain to which it leads, nor in any part of the soil-pipe except such as may be necessary in the construction of the water-closet. The waste-pipe from a slop-sink must conform to the same requirements as a soil-pipe. The waste-pipes from any other sink, bath, or lavatory, the overflow pipe from any cistern and from any "safe" under a bath or water-closet, and every pipe for conveying waste water, must be taken through an external wall and must discharge in the open air over a channel leading to a trapped gully grating at least 18 in. distant.

(*l*) *Water-closets* must have a window opening directly into the external air, and measuring 2 ft. by 1 ft. clear of the frame; and, in addition to the window, adequate means of constant ventilation by air-bricks, air-shafts, etc. Such closets, if within the building, must adjoin an external wall. The water must be supplied to a water-closet by means of a special cistern. The apparatus must be suitable for effectual flushing and cleansing of the basin; the basin must be made of non-absorbent material, and of such shape and capacity as to receive and contain a sufficient quantity of water, and to allow all filth to fall free of the sides directly into the water. "Containers" and "D-traps" are forbidden.

(*m*) *Earth-closets* are subject to the same conditions as water-closets so far as regards position, lighting, and ventilation. Proper arrangements must be made for the supply of dry earth, and its effectual and frequent application to the excreta; also for convenience of scavenging, and for exclusion of rainfall and drainage. The receptacle for excreta, whether fixed or movable, must be so constructed as to prevent absorption or escape of the contents, and to exclude rainfall and drainage; if fixed, its capacity must not be greater than may suffice for (3 months) nor in any case greater than (40 ?) cub. ft., and it must in every part be (3 ?) in. above the ground. (The maximum limit of size may with advantage be reduced to 2 cub. ft. in the case of earth-closets placed inside houses.)

(*n*) *Privies* must not be erected within 6 ft. of a dwelling, public building, or place of business, nor within (50 ?) ft. of any water likely to be used for drinking, or domestic purposes, or for manufacturing drinks, nor otherwise in such a position as to entail danger of the pollution of such water. Privies must be built so as to admit of convenient scavenging, without carrying the contents through any dwelling, public building, or place of business. There must be an opening for ventilation at the top; the floor must be paved, and raised 6 in. above the ground in all parts, with a fall of half an inch per foot towards the door. The receptacle may be fixed or movable. If movable, as in pail-closets, the floor of the area beneath the seat must be flagged or asphalted, and raised 3 in. above the ground-level, and all the sides of the said area must be made of flag, slate, or brick, at least 9 in. thick, and rendered in cement. If the receptacle is fixed, it must be in every part 3 in. above the ground-level, and its capacity must not exceed 8 cub. ft.;* means must be provided for the application of ashes and dry refuse to the excreta, and for the exclusion of rainfall and drainage, and for convenient access for scavenging; the materials and construction must be such as to prevent absorption or leakage, and there must be no connexion with any drain.

(*o*) *Ashpits* must not be constructed within 6 ft. of any dwelling, public building, or place of business, nor within (50 ?) ft. of any water likely to be used for drinking or domestic purposes, etc., nor otherwise in such a position as to entail danger of the pollution of such water. Ashpits must be so placed and constructed as conveniently to allow of scavenging without carrying the contents through any dwelling, public building, or place of business. The capacity must not exceed 6 cub. ft. or such less capacity as may suffice for a period not exceeding one week. The walls must be of flag, slate, or brick, at least 9 in. thick, and rendered inside with cement; the floor must be flagged or asphalted, and raised at least 3 in. above the ground-level. The ashpit must be roofed and ventilated, and provided with a door so arranged as to allow of convenient removal of the contents, and to allow also of being closed and fastened. The ashpit must not be connected with any drain.

(*p*) *Cesspools* must not be constructed within (50 ?) ft. of any dwelling, public building, or place of business, nor within (100 ?) ft. of any water likely to be used for drinking, or domestic purposes, or for manufacturing drinks, or otherwise in such a position as to entail danger of pollution of such water. Cesspools must be so constructed and placed as conveniently to admit of scavenging and cleansing without carrying the contents through any dwelling, public building, or place of business. They must not be connected with any sewer. They must be covered over by an arch or otherwise, and adequately ventilated; and must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 in. of clay.

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* These dimensions are based upon the assumption of weekly scavenging.

(*q*) *Closure of premises unfit for occupation.*—The **S.A.** may, under certificate from the **M.O.H.** or Surveyor, declare any building or part of a building erected after ...... unfit for habitation, and order it to be closed until rendered fit for habitation. Opportunity must be given to the owner to show cause why such order should not be made.

(*r*) *Plans and sections* must be submitted, showing in detail the construction of all proposed new streets or buildings. (The Public Health Act, s. 158, requires that the **S.A.** shall signify their approval or disapproval of the plans within a month after receiving them.)

(*s*) *Inspection.*—Notice must be given to the Surveyor of the dates upon which work is to be commenced, and upon which any sewer, drain, or foundation is to be covered up; notice must also be given of the completion of the work. Free access for inspection must be afforded to him at all times during the progress of the work.

(*t*) *Demolition of illicit works.*—If any work to which the bye-laws apply is done in contravention of such bye-laws, the **S.A.** are empowered to remove, alter, or pull down such work.[*]

[*] The Model Bye-laws contain no provision for the sewerage of new streets, owing to the wide variation in the conditions in different localities. "It may be doubted whether any powers, which under such bye-laws may be lawfully assumed by Sanitary Authorities, will, as regards extent and efficacy, compare with the powers which they derive from the express provisions of the Public Health Act."—**L.G.B.** *Circular to Urban* **S.A.**

5. **Slaughter-houses.** (*a*) *Licences.*—Applications for licence of existing premises, or erection of new slaughter-houses, must be made upon a specified form, and must include full particulars as to the position, form, area, cubic space, etc., of the buildings and appendages; materials and construction of walls and floors; means of water supply, drainage, lighting, and ventilation; means of access for cattle; number, position, and size of stalls or lairs, and number of animals to be accommodated therein, distinguishing oxen, calves, sheep, and swine. The boundaries must also be shown, and, in the case of old premises, particulars as to the ownership and the applicant's tenure must be given.

(*b*) *Registration.*—If the **S.A.** approve the application, a licence shall be issued to the applicant, and must be registered by him at the office of the **S.A.**

(*c*) *Inspection.*—Free access to every slaughter-house for the purpose of inspection must be afforded at all reasonable times to the **M.O.H.**, Inspector, Surveyor, and Committees appointed by the **S.A.**

(*d*) *Water* must be supplied to every animal kept in a lair prior to slaughter.

(*e*) *Mode of slaughter.*—Cattle must be secured by the head so as to be felled with as little pain as practicable.

(*f*) *Drainage, water supply, and ventilation* must be kept in efficient order.

(*g*) *Cleanliness.*—The walls and floor must be kept in good order and repair, and must be thoroughly cleansed within three hours after any slaughtering; the walls and ceiling must be limewashed within the first ten days of March, June, September, and December respectively.

(*h*) *Animals not to be kept.*—No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting or otherwise.

(*i*) *Removal of refuse.*—Suitable vessels made of non-absorbent materials, and provided with close-fitting covers, must be provided for the reception of blood, manure, garbage, and other refuse; all such matters must be placed in these vessels immediately after the slaughtering; the refuse must be removed within 24 hours, and the vessels forthwith cleansed. All skins, fat, and offal must be removed within 24 hours.

"The Board have considered that the statutory terms do not warrant........ regulations directly affecting the structure of the premises. But......in the exercise of the discretionary power of licensing which has been conferred upon the **S.A.**, the following rules as to site and structure should influence their decision upon each application for a licence:—

"1. The premises ...... should not be within 100 ft. of any dwelling-house; and the site should be such as to admit of free ventilation by direct communication with the external air on two sides at least of the slaughter-house.

"2. Lairs for cattle in connexion with the slaughter-house should not be within 100 ft. of a dwelling-house.

"3. The slaughter-house should not in any part be below the surface of the ground.

"4. The approach to the slaughter-house should not be on an incline of more than 1 in 4, and should not be through any dwelling-house or shop.

"5. No room or loft should be constructed over the slaughter-house.

"6. The slaughter-house should be provided with an adequate tank or other proper receptacle for water, so placed that the bottom shall not be less than 6 ft. above the level of the floor of the slaughter-house.

"7. The slaughter-house shall be provided with means of thorough ventilation.

"8. The slaughter-house should be well paved with asphalt or concrete, and laid with proper slope and channel towards a gulley, which should be properly trapped and covered with a grating, the bars of which should not be more than ⅜ in. apart. Provision for the effectual drainage of the slaughter-house should also be made.

"9. The surface of the walls in the interior of the slaughter-house should be covered with hard, smooth, impervious material to a sufficient height.

"10. No water-closet, privy, or cesspool should be constructed within the slaughter-house. There should be no direct communication between the slaughter-house and any stable, water-closet, privy, or cesspool.

"11. Every lair for cattle in connexion with the slaughter-house should be properly paved, drained, and ventilated.

"12. No habitable room should be constructed over any lair."—L.G.B. *Memorandum.*

6. **Houses let in lodgings (or "tenements").** (*a*) *Definitions.*—A "lodging-house" is defined as a house or part of a house intended for the working-classes, let in lodgings, or occupied by members of more than one family. The "landlord" means the owner within the meaning of the P.H. Act, 1875; "tenant" means the person who, whether as owner or otherwise, has an interest in the premises and is entitled to let lodgings and for the time being to receive profits from such letting; and a "lodger" is a person to whom any room or rooms in such house, or part of a house, have been let for his use and occupation. (*b*) *Limitation as to class.*—(1) On a rent limit, say of 3s. to 8s. if unfurnished, or 5s. to 10s. if furnished; or (2) where the landlord resides on the premises, and the letting is to not more than one lodger. (*c*) *Cubic space.*—A room used exclusively as a sleeping-apartment shall not be so used at any one time by a greater number of persons than will admit of the provision of 300 cub. ft. of air-space for each person over 10 years of age, and 150 cub. ft. for each person under 10 years. A room not exclusively used as a sleeping-room shall not be used at any one time by a greater number of persons than will admit of the provision of 400 cub. ft. of air-space for each person over 10 years of age, and 200 cub. ft. for each person under 10 years. (*d*)

Tenant to furnish returns.—The tenant shall, if required by the **S.A.**, furnish the following particulars: (1) Number of rooms in the house; (2) number of rooms let in lodgings or occupied by members of more than one family; (3) the manner of use of each room; (4) the number, age, and sex of the occupants of each room used for sleeping; (5) full name of the lessee of each room; (6) the rent payable by each lessee. (*e*) *Inspection.*—Facilities for inspection shall be afforded to the **M.O.H.**, Inspector, or Surveyor at all times by the tenant and lodgers. (*f*) *Closet accommodation.*—The landlord shall provide sufficient closet accommodation, in the proportion of at least one closet for every twelve persons of the maximum number of lodgers allowed by the bye-laws, and maintain the closets and all necessary appurtenances in efficient order. •All closets must be kept clean, and supplied with dry earth (if earth-closets) or water (if water-closets) as required.* (*g*) *Ashpits* must be maintained in repair by the landlord, and must be kept clean; no filth or wet refuse must be thrown into an ashpit designed for dry refuse only. (*h*) *Cleanliness of rooms.*—The floors of all rooms must be swept daily, and washed every week. All windows, all wood, stone, or metal fixtures, and all painted surfaces must be kept clean. All solid or liquid filth or refuse must be removed from every room every day, and all receptacles thereof cleansed. (*i*) *Keeping of animals.*—No animal must be kept upon the premises in such manner as to render the premises filthy. (*j*) *Water storage.*—All cisterns for storing water must be kept clean. (*k*) *Ventilation.*—The landlord must maintain in efficient order the means of ventilation of all parts of the house. (*l*) *Annual cleansing of premises.*—

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* If the bye-laws respecting new streets and buildings are not in force in the district, those of them which refer to the construction of closets may be introduced here.

Every year, in the month of ...... the landlord must cleanse every part of the premises, and whitewash the ceilings and walls throughout the house, except surfaces to which limewashing may be unsuitable, and these must be cleansed and, if necessary, painted. (*m*) *Yard and open spaces.*—The yard and all open spaces must be kept clean and in good order. The yard must have a hard, impervious pavement laid upon concrete, and sloped to a channel leading to a trapped gulley grating; all these must be kept in repair by the landlord. (*n*) *Ventilation of sleeping-rooms.*—The window of every sleeping-room shall be kept open for an hour in the forenoon and an hour in the afternoon, except in case of stress of weather, or occupation of the room by a sick person, or other sufficient reason. (*o*) *Infectious diseases.*—The tenant must immediately give written notice to the **M.O.H.** if he learns that any person in the house is ill of an infectious disease. A lodger must immediately give written notice to the **M.O.H.**, and verbal or written notice to every lodger in the house, if he has reason to believe that any occupant of any room is ill of an infectious disease. Where a Justice's order has been obtained for the removal to a hospital of a person suffering from any dangerous infectious disease, both the tenant and the lodger in whose tenement such sick person is shall take such steps as may be requisite on their respective parts for the safe and prompt removal of such person; and shall adopt all such precautions as may be most suitable, in accordance with any instructions of the **M.O.H.**

Where a duty imposed upon or a prohibition applied to the landlord or tenant of a lodging-house is by any bye-law expressly imposed or applied subject to the provisions of these bye-laws, proceedings shall not be taken against the landlord or tenant for an offence against the bye-law unless and until the landlord or tenant, after service upon him of a notice in writing from the Council, signed by the **M.O.H.**, or clerk of the Authority, requiring him within a reasonable time specified in the notice to comply with the bye-law, has failed to comply with the bye-law within that time.

The landlord is made responsible for the structural repair of every part of the premises, for the efficiency of the closets and of the means of ventilation, for the annual cleansing, and for the detailed cleansing of all parts (including yards, closets, staircases, and passages) which are not let for the sole use of one tenant. The tenant or lodger is responsible for the cleanliness and management of the rooms rented by him, and of all other parts of the premises of which he has the sole use.

7. **Cemeteries.** (*a*) *Definitions.*—A "grave" is defined as a burial-place formed in the ground by excavation, and without any internal wall of brickwork or stonework, or any other artificial lining. A "vault" is an underground burial-place of any other construction. (*b*) *Vaults.*—Every vault shall be enclosed with walls of brick or stone, solidly put together with good mortar or cement. (*c*) *Common graves.*—Not more than one body shall be buried at any one time in a grave in respect of which no exclusive right of burial has been granted. (Exception is made in the case of two or more members of the same family.) Such a grave shall not be reopened for the purpose of a further burial within eight years after the burial of a person aged less than 12 years, nor within fourteen years after the burial of a person aged more than 12 years. (Exception is made in the case of members of the same family.) (*d*) *Minimum covering of earth.*—No part of a coffin shall be buried at a less depth than 3 ft. below the ground adjoining the grave, if it contains the body of a person aged less

than 12 years; nor at a less depth than 4 ft. if the age of the deceased was over 12 years. A layer of earth, not less than 1 ft. in thickness, shall be interposed between every coffin and the coffin nearest to it. (e) *Closure of vaults.*—A coffin buried in a vault shall, within twenty-four hours after burial, be wholly and permanently embedded in and covered with good cement concrete, not less in any part than 6 in. in thickness; or wholly and permanently enclosed in a separate cell, constructed of slate or flag, not less than 2 in. thick, and jointed in cement, or of brick in cement, and in such manner as to prevent as far as practicable the escape of noxious gas.

8. **Mortuaries.**—The only provisions of sanitary importance suggested in this series are the following: A body deposited in the mortuary shall be removed therefrom for interment within........... days after death; but if the deceased has died of an infectious disease, the body shall be removed for interment within............days after death.

A **L.G.B.** Memorandum makes the following general suggestions in regard to construction and management:—

The buildings should be isolated and unobtrusive, but substantial, structures of brick or stone. Every chamber for the reception of corpses should be on the ground floor. In addition to such chamber there should be a waiting-room, a caretaker's house, and a shed or outhouse. Every mortuary chamber should be lofty, and there should be a ceiling or a double roof, with an intervening space of 8 in., for the sake of coolness. The area should be sufficient to allow freedom of movement between the slabs. The windows should be on the north side, if practicable; if otherwise, they should have external louvre blinds. Louvres, or air-gratings, under the eaves will be the best means of ventilation. The pavement must be even and close, and a cement floor is preferable. The slabs should be of slate, and 2½ ft. to 3 ft. from the floor. Water should be laid on within the chamber. The walls and ceiling should be whitewashed, and the outside of the roof also whitened. There should be at least two chambers, one of which may be reserved for bodies of persons who have died of infectious disease.

There should be a resident caretaker, and bodies should be received at any hour of the day or night. A register should be kept.

9. **Offensive trades.**—The offensive trades in regard to which Model Bye-laws have been issued by the **L.G.B.** are those of—

Blood-boiler.
Bone-boiler.
Fellmonger.
Soap-boiler.
Tallow-melter.
Tripe-boiler.
Blood-drier.
Leather-dresser.
Tanner.
Fat-melter or extractor.
Glue-maker.
Size-maker.
Gut-scraper.

Of these the first six only are specifically mentioned in s. 112 of the Public Health Act, the rest being examples of "other offensive trades."* The same general provisions appear in all, with numerous additions or variations as required by the conditions of the particular trade in question.

The summary on pp. 728–9 will show their general character.

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* A *blood-boiler* boils blood or treats it with steam and prepares it for manure manufacture by reducing it to powder in heated "driers." A *bone-boiler* extracts fat and gelatin from bones by boiling under pressure. The *fellmonger* prepares dry or fresh skins for leather-dressing. Fresh skins are beaten with a mallet, then soaked in water and milk of lime, after which the hair or wool is plucked off. Fat, tallow, oil, etc., together with alkali solutions (K or Na) termed "lyes," are boiled by the *soap-boiler* preparatory to soap manufacture. *Tallow-melting* is a similar process of treating rendered fat without alkalis. The liquid is run off into barrels. A *tripe-boiler* cleans and boils the stomach of the ox or sheep, and prepares it for human food. Other offensive trades include such processes as involve the collection or treatment of large quantities of animal matter or substances likely to become a nuisance

(i.) *Storage of offensive materials.*—Materials not required for immediate use or treatment shall be so stored as to prevent effluvium. (ii.) *Offensive vapours* emitted during boiling, melting, etc. The best practicable means shall be adopted for rendering such vapours innocuous. The vapour shall either (*a*) be discharged into the external air in such a manner and at such a height as to admit of its diffusion without noxious or injurious effects, or (*b*) shall be passed directly from the pan, etc., through a fire, or (*c*) into a condensing apparatus, or (*d*) through a condensing apparatus and then through a fire, in such manner as effectually to consume the vapour or deprive it of all noxious or injurious properties. (iii.) *Drainage* must be kept in efficient order. Bone-boilers are required to cool all hot liquid refuse before passing it into any drain. (iv.) *Floors* must be kept in good order so as to prevent the absorption of filth. In respect of several trades it is required that at the close of every working-day the floors shall be swept (e.g. tanner's, leather-dresser's) or washed (blood-drier's, etc.) or scraped, or otherwise cleansed. All refuse collected by sweeping or scraping shall be forthwith removed from the premises in covered receptacles, unless intended to be forthwith subjected to further trade processes on the premises. (v.) *Walls* shall be kept in good order so as to prevent the absorption of filth, and, if necessary, be scraped. Limewashing of walls and ceiling twice yearly is required in regard to certain trades—fellmonger's, for example. (vi.) *Apparatus*, including all implements and vessels, to be kept clean; daily cleansing is required in some cases. (vii.) *Waste lime* (fellmonger's, tanner's) must be removed at once, and under close cover. (viii.) *Tanks* used by fellmongers for washing or soaking skins shall be emptied and cleansed as often as necessary to prevent effluvia.

(ix.) Free access for the purpose of inspection shall at all reasonable times be afforded to the **M.O.H.**, Inspector of Nuisances, Surveyor, or any committee specially appointed by the **S.A.** on that behalf.

10. **Hop-pickers.** (*a*) *Application.*—These bye-laws apply to all tents, sheds, barns, or other places occupied as temporary dwellings by hop-pickers, but not to places inhabited throughout the year. (*b*) *Habitable condition.*—Such temporary habitations are required to be clean, dry, weatherproof, and to be ventilated and lighted. (*c*) *Closet accommodation.*—There must be adequate privy accommodation for the separate use of each sex. (*d*) *Water.*—There must be a sufficient supply of good water for drinking, cooking, and washing. (*e*) *Cooking.*—There must be a separate cooking-place for every fifteen persons authorized to be received. (*f*) *Area.*—An average floor-space of 15 sq. ft. must be allowed for each occupant, but two children under 10 years of age may be counted as one adult. (*g*) *Bedding.*—Clean straw or other suitable material must be supplied for bedding, and renewed as required. The beds must be screened off in places occupied by adults of different sexes. (*h*) *Cleansing.*—The premises and appointments must be thoroughly cleansed immediately before occupation, the internal surfaces limewashed, and all offensive accumulations cleared away. The cleansing must be repeated as required from time to time during the period of occupation.

(Similar bye-laws may be made in respect of the accommodation of persons engaged in picking fruit or vegetables.)

11. **Means of escape from fire, in factories and workshops.**—Buildings of more than one storey must, if any part above the ground floor is used as a factory or workshop, have adequate fixed stairs (with handrails), lighted, and giving free access

from every such part to the ground floor, and, where practicable, to an open space outside. In new factories or workshops, buildings, and buildings newly altered structurally for that purpose, the stairs must be of fire-resisting material, e.g. brick, stone, concrete, iron, steel, copper, hard timber (oak, teak), or timber rendered uninflammable.

If any floor over 30 ft. from the ground is used as a factory or workshop, and either more than ten persons are employed, or readily inflammable materials are stored, there must, *in addition*, be (1) an external fire-resisting staircase, or (2) an efficient fire-escape, or (3) ready access to the roof, and, where practicable, to the roof of an adjoining building. The window or door leading to (1), (2), or (3) must be distinctively marked.

Every room (of a factory or workshop) in which persons are habitually employed must have at least one window (distinctively marked if there be others) opening easily at the sill level to an extent allowing easy escape.

12. **Prevention of waste of water.**—These bye-laws relate to (*a*) the composition of the pipes to be used for the conveyance and distribution of water; (*b*) the protection of the pipes; (*c*) the provision of suitable stopcocks, taps, cocks, and valves; (*d*) cisterns, hot-water apparatus, baths, and lavatory basins and overflow pipes; (*e*) flushing apparatus for water-closets and urinals; and (*f*) the use of automatic flushing apparatus, hoses, etc.

CHAPTER XXIII

VITAL STATISTICS

Population.—A census has been taken decennially since 1801, and gives detailed information regarding each county, union, registration district and sub-district, and urban district. The chief data are : (1) the total number of inhabitants in each area, (2) their age, (3) sex, (4) occupation, (5) condition as to marriage, (6) birthplace, (7) nationality, etc. The day fixed is usually the last day of the first quarter of the year. The census for 1911 for England and Wales yielded a population of 36,070,492. The estimated population in 1916 was 36,250,000.

The official estimate of population at the middle of any year is made by assuming that increase or decrease has gone on since the last census at exactly the same rate as between that and the previous census, at geometrical progression.

If $p =$ the population in any given year, and $r =$ the factor of annual increase, then in one year the population will become $p+r$, in two years $p+r^2$, and n n years $p+r^n$.

Given a census population of x in 1901, and y in 1911, the rate of *decennial* increase is $\frac{y}{x}$, that of *annual* ncrease $\sqrt[10]{\frac{y}{x}}$, and that of *quarterly* increase $\sqrt[40]{\frac{y}{x}}$. Hence—

$$\log. y - \log. x = \text{log. rate of decennial increase,}$$

$$\text{and } \frac{\log. y - \log. x}{10} = \text{log. rate of annual increase,}$$

$$\text{and } \frac{\log. y - \log. x}{10 \times 4} = \text{log. rate of quarterly increase.}$$

Thus the logarithm of the estimated mid-year population for 1911 is, $\log. y + \frac{\log. y - \log. x}{10 \times 4}$; and for 1918,

$$\log. y + \frac{\log. y - \log. x}{10 \times 4} + 7\,\frac{\log. y - \log. x}{10}.$$

The following calculation of the mid-year 1915 population from census data of 1901 and 1911 may serve as an example :—

(*a*) The census population of 1911 was 100,970; log. 100,970 =	5·0041924
(*b*) The census population of 1901 was 87,842; log. 87,842 =	4·9437022
(*c*) By subtraction, the logarithm of *decennial* increase was, therefore	0·0604902
(*d*) Dividing by 10, the log. of *annual* increase is obtained . . . . . . =	0·0060490
(*e*) Again dividing by 4, the log. of *quarterly* increase is obtained . . . . =	0·0015122
(*f*) Adding together log. 1911 census population (*a*), and log. quarterly increase (*e*), and four times log. annual increase (*d*), we get the log. of 1915 mid-year population . =	5·0299017

And on referring to the tables, the number corresponding to this logarithm is found to be 107,128.

The factors given by the Registrar-General for 1911 and subsequent years are as follows:—

1911 . .	0·02634780	1916 . .	0·56787619
1912 . .	0·13242746	1917 . .	0·67958101
1913 . .	0·23960799	1918 . .	0·79244797
1914 . .	0·34790096	1919 . .	0·90648664
1915 . .	0·45731880	1920 . .	1·02170833

"The population of any district at the middle of any year 1911–1920 is calculated by adding to the population enumerated in 1911 the product of the increase of population in the last intercensal period and the factor for the year in the above series. In the case of a decreasing population the product of the intercensal decrease multiplied by the factor should be deducted from the population enumerated in 1911."

There are obvious limitations to the value of such an estimate. The rate of increase is not the same in the centre of a town as in the growing suburbs. New houses are springing up and becoming inhabited in the latter, apart from the "natural increase" by excess of births over deaths; while in the former there may even be an actual decrease of population, owing to the displacement of dwellings by business premises.

If the estimate is very wide of the mark, some indication of this may be given by an apparently excessively high or low birth-rate and death-rate; by the number of inhabited houses,* as ascertained from the rate-books or other sources; by returns of those who by migration have evaded vaccination; by returns of school attendance; or by inference from the condition of the local industries. In villages, where the local conditions are well known, a better estimate can sometimes be made from such data than from calculations based upon a remote census.

The *actual increase* is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. The excess of births over deaths is termed the *natural increase*. As regards towns, the *actual* is, upon the average, greater than the *natural* increase, since there is a tendency to migration from rural to urban districts. In times of depression of local trade there is emigration to other districts; whereas, when trade is flourishing, labour is attracted from rural districts and from other towns.

The **age-distribution** of a population is ascertained by each census, and may be assumed to remain constant until the next census; that is, the rate of increase is assumed to be uniform at all ages. There are, however, very material differences among towns, and between town and country, in this respect, and as the tendency to death is much greater among the very young and very old, it becomes important to allow for these variations in drawing inferences from death-rates as to the health conditions of a community. Owing to the immigration of young adults from rural districts, town populations almost always contain a larger proportion of persons between 15 and 45 than is found in the country at large; and hence a higher birth-rate and (under equal health conditions) a lower death-rate are to be expected a priori.

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* The average number of persons per inhabited house is fairly constant for each locality, though varying considerably in different towns, according to the proportion of "tenement houses" and houses occupied by one family.

Births must, according to the Notification of Births Extension Act, 1915, be notified within 36 hours. This applies to every child born after the twenty-eighth week of pregnancy, whether alive or dead.

More males than females are born, in the proportion of nearly 104 to 100, but this excess is diminishing. Owing to the higher death-rate among males, the survivors of the two sexes are nearly equal in number at the end of the first year of life, and thenceforward the females are in the majority. Stillbirths, which Farr estimated at 4 per cent. of the total births, are now included in the notification returns.

The *birth-rate* is the proportion of births in one year per 1,000 persons living; that is—

$$\frac{\text{No. of births in the year}}{\text{mid-year population}} \times 1{,}000.$$

For shorter periods, such as quarters or weeks, the rate is calculated on the assumption that the like periods throughout the year would yield the same proportion: so that the birth-rate during $\frac{1}{x}$th part of a year is—

$$\frac{\text{No. of births during the period in question}}{\text{mid-year population}} \times x \times 1{,}000.$$

For ordinary purposes it is sufficient to regard the year as consisting of 365 days, or 52 weeks; but if greater precision is required, the astronomical year may be used—namely, 365·24 days, or 52·177 weeks.

The English birth-rate, which was 35·4 in 1871-80 and 36·3 in 1876, is declining, and was only 21·6 in 1916 (785,454 births in England and Wales). It is higher in towns, and in times of prosperity; lower in rural districts, and in times of depression of trade.

This *crude birth-rate* is calculated on the total population at all ages. But other bases of calculation would be—(*a*) female population of child-bearing age, 15–45 years (*fertility-rate*); (*b*) population of fertile women who are married, 15–45 years (*legitimate fertility-rate*); (*c*) unmarried and widowed female population, 15–45 years (*illegitimate fertility-rate*). The ratio of births is dependent on the proportion of these groups of females to the total population, on the average age of married women, and on the prevalence or otherwise of methods of deliberate restriction of child-bearing. Fertility varies in different parts of the country. *Illegitimacy* (about 4 per cent. of total births) is usually stated in the form of the proportion of illegitimate births, either to total births, to total population, or per 1,000 of unmarried and widowed females aged 15–45 years. The *mean annual rate of increase* of the population is the difference between the means of birth- and death-rate. In 1876–80 it was 14·6 per 1,000; in 1914 it had fallen to 9·8 per 1,000 living.

Deaths must, according to the Births and Deaths Registration Act, 1874, be registered within five days.

Death-rates are calculated in the same way as birth-rates. The death-rate in England and Wales declined from 22·4 in 1851–70 to 18·2 in 1891–1900, 16·0 in 1901–5; 14·4 in 1906–10, and 14·0 in 1916, when the annual total of deaths was 508,227. Local death-rates require certain corrections, as below, in order to render them comparable with that of the whole country. The forms of death-rate which must be considered in estimating the health of a community are—(*a*) the crude death-rate, (*b*) the crude death-rate corrected for residents and non-residents, (*c*) the corrected or standardized death-rate, (*d*) the comparative mortality figure, (*e*) the infant-mortality rate, (*f*) the zymotic death-rate, (*g*) the death-rate of special diseases, and (*h*) the expectation of life, probable duration of life, and the mean age at death. Particulars respecting these returns will now be given.

Correction for non-residents.—The deaths of strangers who happen to die in the district should be excluded. Without this correction the true rate may be seriously overstated if the district contains large institutions admitting non-residents. Similarly, the deaths of residents dying outside the district should be included.

Correction for age- and sex-distribution is made, indirectly, by a "factor" obtained as below, which is greater than unity in nearly all towns, and less than unity in rural districts. Multiplying the local death-rate by the factor, the *corrected local death-rate* is obtained. This is more accurately described as the *standardized death-rate.* It may also be calculated by a "direct" method.

For a locality it is the death-rate for the whole country, recalculated on the basis of the *local* age and sex distribution, and may be found as follows. The age- and sex-distribution per million of both local and general *population* are separately determined from census data. The recorded *deaths* (in the whole country) are distributed in the same groups, and the number of deaths in each group corrected in the proportion of the local to the general population at those ages. If, for example, the males living at a given group of ages are x per million of the local population and y per million of that of the whole country, and the male deaths (in the whole country) at those ages are m, the corrected number of deaths is $m \times \frac{x}{y}$. Adding together all the corrected numbers we have a corrected total a, differing from the recorded total b (of deaths in the whole country), and representing the deaths which would have occurred had the age- and sex-distribution been the same as that of the locality. Hence $\frac{a \times 1,000}{\text{population of whole country}}$ is the *standard death-rate* for the locality. The $\frac{\text{death-rate of whole country}}{\text{standard local death-rate}}$ is the factor sought, and is equal to $\frac{b}{a}$.

The *comparative mortality figure* for the district is—

$$\frac{\text{corrected local death-rate}}{\text{death-rate for the whole country}} \times 1,000.$$

It is used for comparing the standardized death-rate of any given area with the death-rate for the whole country, and for comparative purposes in occupational mortality.

Urban death-rates are higher than rural, and the correction for age- and sex-distribution increases the inequality. The causes of this are complex, and include differences of occupation and mode of life, and the direct and indirect consequences of aggregation of population. Ogle found that in 1871–80 the death-rates of districts increased with the *density of population*, if exceeding 400 per square mile, but below that point the influence was not apparent. (The average density for England and Wales exceeds 500 per square mile, or 0·8 per acre.) Farr concluded that, other things being equal, urban death-rates vary as the twelfth root of the density; but this rule is of limited practical application, since many variable conditions are involved, and notably the degree of crowding of rooms. Newsholme showed that in 1889 the death-rate among the 20,000 inhabitants of Peabody Buildings (density, 750 per acre) was lower than that of London generally (average density, 49 per acre).

The death-rate is diminishing in both urban and rural districts, but more rapidly in the former than in the latter.

The death-rate among males is higher than among females, subject, however, to exceptions at certain age-periods, notably 10–20, as Appendix I. shows. Both are decreasing, but the saving of life is chiefly effected in the earlier age-periods, and is less conspicuous at ages over 40, owing, perhaps, partly to the increasing wear and tear of modern life, and partly to the more frequent survival of weakly persons at middle life who under former conditions would have died in youth. In both sexes the tendency to death is high in infancy, reaches its minimum in the 10--15-year age-period, and afterwards increases steadily throughout life.

Infant mortality is calculated upon the birth-returns, which are precise and free from many of the errors attendant upon estimates. The formula is—

$$\frac{\text{deaths of children under 1 year}}{\text{registered births}} \times 1{,}000.$$

Influence of the birth-rate upon the death-rate.—Other things being equal, a high birth-rate *in a given year* would theoretically increase the death-rate, since the mortality among the newly born is much greater than that of the population generally. But a high birth-rate implies (*a*) a large proportion of persons at the reproductive ages, and in a few years (*b*) a new population of children and young adults, since under the most adverse conditions a large majority of the infants survive. The mortality among both classes (*a*) and (*b*) is low, and more than balances the higher mortality in the first year or two of life. (*Farr.*)

Zymotic death-rate is a term formerly applied to the aggregate death-rate from the "seven principal zymotic diseases"—smallpox, measles, scarlet fever, diphtheria, whooping-cough, "fever" (typhus, simple continued, and enteric), and diarrhœa. It is liable to great fluctuation, according to the epidemic prevalence of one or other of the diseases included.

Cause of death.—The death-returns obtained from the registrars are copied from the certificates signed by medical practitioners or coroners. Very commonly two or more causes are assigned—one being regarded as "primary" and the other as "secondary." As only one cause in each case can be accepted for statistical purposes, preference should be given to (1) infective or specific diseases, and (2) primary as compared with secondary causes.

Progressive changes are noticeable, in regard to the death-rate from certain well-defined diseases, in the direction of increase or decrease. It may extend to all ages, or be more or less limited to certain periods of life. The change does not necessarily affect both sexes alike—phthisis, for example, having decreased much more rapidly among females than among males

Decrease is manifest in the mortality from smallpox, scarlet fever, diarrhœa, typhus, enteric fever, phthisis, convulsions, croup, diseases of the digestive system, and diseases of parturition; also from "ill-defined causes." As regards the first five, the reduction is real, and attributable in great part to improved measures of precaution and sanitation. Phthisis has been greatly lessened, but there has probably been some transfer of cases by improved diagnosis from phthisis to other respiratory diseases. Better diagnosis and better certification are responsible for the gradual disappearance of "croup," "convulsions," and "simple continued fever," and also, of course, for the lessened total of "ill-defined diseases."

On the other hand, there is a distinct increase in the mortality attributed to cancer, diabetes, and diseases of the nervous and urinary systems.

The *cancer* death-rate in 1861–70 was 387 per million, in 1871–80 473, in 1881–90 589, in 1891–1900 758, in 1906–10 939, and in 1915 1121 (39,847 deaths); certain areas yielded exceptionally high rates. Age-distribution of population is important in this connexion, since the mortality is chiefly at ages over 35. Cancer mortality is higher among women than men. The increase is partly due to improved diagnosis, and to inclusion of forms of malignant disease not previously grouped with cancer. Diagnosis is more accurate in females than males, in middle age than old age, and in large towns than rural districts. Cancer mortality among males arises chiefly from disease in the stomach and alimentary system, among females from disease in the uterus, breast, stomach and alimentary system. The age-incidence is steadily rising. Recent researches in this country, while showing a wider range among lower animals than had been suspected (*Bashford*), have not confirmed the suggestion that cancer is an infective disease due to a micro-organism. Instances are met with of repeated occurrence of the disease in "cancer houses," but little is known of dependence upon dietetic or other causes, and no special preventive measures are in force.

Deaths due to protracted sequelæ of acute specific diseases are usually credited to the secondary and not to the true primary cause. It will be found that the mortality from bronchitis and pneumonia is increased by outbreaks of influenza, whooping-cough, and measles, and scarlet-fever prevalence is followed by deaths referred merely to kidney diseases.

Sex has an important bearing upon the mortality from certain diseases, owing partly to differences in constitutional predisposition, and partly to exposure to the conditions favourable or unfavourable to the development of the diseases in question. The male mortality exceeds the female in most well-defined diseases or groups of diseases, but there are important exceptions, such as diphtheria, whooping-cough, erysipelas, rheumatism, cancer, and anæmia (including chlorosis and pernicious anæmia).

Age materially affects the average liability to certain diseases, by reason of physiological changes, acquired protection, and degree of exposure. Vaccination completely alters the age-curve in smallpox. In all protective diseases the accumulation of protected survivors must be allowed for before any lessened average susceptibility at higher ages can be inferred. The maximum mortality from smallpox, whooping-cough, erysipelas, and diarrhœa occurs in the 1st year of life, from measles in the 2nd, from scarlet fever in the 3rd, and from diphtheria in the 4th. A second maximum follows in smallpox about the 25th year; and from about the same point diarrhœa mortality again rises until the end of life. Phthisis is at its minimum from the 5th to the 10th year, increases up to the 45th, and afterwards diminishes. Cancer mortality is small in the earlier years, but increases rapidly from about the 25th year to the end of life. The single curve, with a minimum from the 10th to the 15th year, which is characteristic of the total death-rate, is common also to the mortality from nervous, respiratory, digestive, and urinary diseases, and violence; diseases of the circulatory system increase steadily in mortality from birth to the end of life. The varying influence of age is seen even in infancy.

The true influence of sex and age cannot be ascertained by returns of mortality alone. The mere number of deaths at each age-period conveys little information, since the numbers living diminish as age advances. Even death-rates for each group tell only of the liability to death, but nothing as to the incidence of sickness or the chance of recovery. As regards notifiable diseases, however, statistics of attacks as well as deaths are available. The variations in incidence and in severity, according to age and sex, are not always parallel, and indeed are often inverse, as in scarlet fever and enteric fever. From the number of persons living, of each sex and at each age-period, it is possible to calculate, for each sub-group, (1) the *incidence* of disease, that is, the *morbidity-rate*, attack-rate or proportion of attacks to population, and (2) the *case-mortality*, or proportion of deaths to attacks. Evidence as to incidence of disease at different ages can be obtained from notification returns, but hospital statistics are misleading, since age materially affects the chances of removal to hospital. As regards case-mortality, however, both hospital and notification data may be admitted.

The **registration of sickness**, as distinct from the bills of mortality, is now in considerable measure practicable owing to (*a*) the compulsory notification of infectious diseases under the Extension Act of 1899 and the Public Health (London) Act, 1891, (*b*) the notification of six industrial poisonings under the Factory Acts (*see* p. 682), (*c*) the medical inspection of school children (*see* p. 252), and (*d*) the National Insurance Act (*see* p. 650). Special attention is also being given to venereal disease, mental deficiency, epilepsy, and the causes of infant and child mortality.

Statistical evidence of the health of communities.—The usual criteria are either actual death-rates (general, "zymotic," or infant mortality, etc.), sickness-rates, or figures representing the average longevity—namely, "expectation of life," "probable duration of life," "mean age at death."

The **standardized death-rate** affords a simple and, in the main, accurate measure of the comparative prevalence of disease. It is untrustworthy if the figures are so small as to be exposed to violent fluctuations; thus, the "weekly death-rate" is only useful in large communities. Other sources of error are (i.) uncertainty as to population, and (ii.) severe epidemics, which may have no definite relation to impaired public health in general.

A high death-rate from enteric fever, diphtheria, or diarrhœa may in general fairly be taken to imply a defective sanitary state; but may also be due to temporary and accidental causes, such as climatic conditions or accidental contamination of milk or water. Little is known of the determining causes of epidemics of smallpox, measles, whooping-cough, and scarlet fever; but their predisposing causes are all widely different, and are for the most part not affected by "sanitary conditions." The death-rate due to such a heterogeneous group as that of the "principal zymotic diseases" connotes nothing as to the health condition of the community in other respects.

Infant mortality is the most sensitive index of the health of a community, partly because (1) of the frailty of infant life, (2) a variety of factors are involved, (3) many of these factors are social and personal as well as environmental. A high infant mortality implies an increased death-rate up to 5 years of age, and a high prevalence of the conditions which determine national physical inferiority. It is higher in urban districts than in rural, among illegitimate children, in the first trimester of life than in any other trimester, and among male children; and it is usually highest in the third quarter of the year (epidemic diarrhœa), particularly in dry, hot summers. In 1915 the infant mortality-rate per 1,000 births in urban and rural districts was as follows:—

AREA (1915).	NORTH.	MID-LANDS.	SOUTH.	WALES.	ENG. & WALES.
London	—	—	112	—	112
County boroughs . . .	131	116	94	114	122
Other urban districts . .	120	100	87	120	107
Rural districts . . .	106	84	78	97	90
All areas	124	102	99	112	110

About one-fifth of the total deaths of infants occur in the first week of life. The chief diseases responsible for a high infant mortality are (*a*) premature birth and congenital defects; (*b*) atrophy, debility, and marasmus; (*c*) convulsions; (*d*) diarrhœal diseases (between 5 and 10 months and due to food causes); (*e*) measles and whooping-cough; and (*f*) bronchitis and pneumonia (due chiefly to exposure to cold and unequable temperatures). Among the prenatal, natal, and postnatal conditions contributing to infant mortality are the age and health of the mother, lack of skilled aid at childbirth, poverty and urban conditions, the industrial employment of women, domestic insanitation and uncleanliness (accentuated in hot, dry summers), maternal ignorance and mismanagement (including inappropriate artificial feeding). The Registrar-General has shown (1911) that infant mortality varies in accordance with social class. In the upper and middle class it was 76·4 per 1,000 (for medical practitioners 39); in the wage-earning class, 132·5; and in tin and salt miners, factory labourers, scavengers, costers, etc., upwards of 190 per 1,000. The average in 1911 was 130 per 1,000 births. Breast-feeding is a natural protection against infant mortality. In addition to the general improvement of sanitation, housing, milk supply, wages, and social conditions, the *means of prevention* obviously include good health of the mother, skilful aid at birth, sound and enlightened infant care and management, the prevention of measles, diarrhœa, and other infantile maladies, breast-feeding, and cleanliness in all respects. Towards these ends the early notification of births, effective midwifery, domestic and municipal sanitation, and the education of elder girls and mothers in infant management are valuable means. The increasing application of these means is no doubt largely responsible for the marked decline in infant-mortality which has occurred in recent years.

	ENGLAND AND WALES.			LONDON.		
	Birth-rate	*Death-rate*	*Infant mort'lity*	*Birth-rate*	*Death-rate*	*Infant mort'lity*
1851–1860	34·1	22·2	154	33·6	23·7	155
1861–1870	35·2	22·5	154	35·4	24·4	162
1871–1880	35·4	21·4	149	35·4	22·5	158
1881–1890	32·4	19·1	142	33·2	20·5	152
1891–1900	29·9	18·2	153	30·2	19·6	160
1901–1910	27·2	15·4	128	27·5	15·7	126

In 1916 the infant-mortality rate for England and Wales was 91, against 132 in 1906; and for London, 89—both the lowest recorded. A substantial decline in infant mortality has occurred in the last ten or twelve years, mainly during the last nine months of infancy, and due largely to improved local sanitary conditions and better nursing and infant management.

A high **phthisis death-rate** may be due to dampness of soil, unhealthy occupations, or overcrowding of dwellings. The death-rate from respiratory diseases (other than phthisis) is also important.

The **mean age at death** is obtained by adding up the ages and dividing by the number of deaths. It is controlled by the birth-rate, and by the age-distribution of the population. A large proportion of infant deaths must necessarily reduce the average age at death.

The **probable duration of life** is the age at which exactly half of any given number of children born will have died. It can only be ascertained from a life-table, and is of no great value. The probable duration of life for males is about 53, and for females 58 years.

The **expectation of life**, at any age, is the average number of years which a person at that age will live, as shown by a life-table. The expectation of life at age 0 (i.e. at birth) is also known as the *mean duration of life.*[*] At other ages than the time of birth it is sometimes termed *mean after-lifetime*, and the present age plus the mean after-lifetime is the age to which a person may expect to survive.

The expectation of life is the true measure of the vitality of a community. The expectation at birth is the most convenient for comparative purposes, but if necessary we can eliminate the influence of infant mortality by taking the expectation of life at a later age.

A **life-table** shows how many, out of a million persons supposed to be born simultaneously, will survive at the end of each year or each term of years. The data required are (1) a census population—that is, a population of which the distribution according to ages and sexes is known; (2) returns of deaths (grouped for each sex in the same age-periods as have been adopted for the census population) for one or more years among this same population. The simplest plan is to take only the deaths in the census year, when the population is known with precision; but as it is important to obtain large numbers, it is convenient to use the death returns of a series of three or more years, in which the census year is central. Thus the 1901 census population may fairly be assumed to be substantially the same as the average population in the years 1900–1–2. A still better method is to take the death returns for a whole intercensal period, and the *mean* population. A separate table should be constructed for each sex.

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[*] The "mean duration of life" differs from the "probable duration of life" just as the arithmetical mean of a list of numbers differs from the middle value of the series. The fact that one term has as many terms above as below it does not render it the mean of the series.

The "mean duration of life" must also be carefully distinguished from the "mean age at death." The latter expression is not employed in reference to a life-table population.

Having decided upon the intervals to be taken (annual or quinquennial), the first step is to ascertain from the census returns the number living at each group of ages, and, from the death returns, the mean annual number of deaths among each group. As already explained, $\frac{\text{number of deaths}}{\text{number living}} \times 1{,}000 = \text{D} =$ the death-rate for that group of ages per thousand living. These D deaths (among 1,000 living) are assumed to be evenly distributed over the whole age-period included in the group, so that half $\left(i.e.\ \frac{\text{D}}{2}\right)$ will occur in the earlier half of the ages, and half in the later.* Hence the 1,000 persons are regarded as decreasing from $1{,}000 + \frac{\text{D}}{2}$ at the beginning of the period to $1{,}000 - \frac{\text{D}}{2}$ at the end of it; and the ratio of the final to the initial population is $\left(1{,}000 - \frac{\text{D}}{2}\right) : 1{,}000 + \frac{\text{D}}{2}$ or $\frac{2{,}000 - \text{D}}{2{,}000 + \text{D}}$. Having found the value of this ratio for each age or group of ages, we have all the data necessary for the construction of a life-table.

For the first year of life the formula is not required. If the infant mortality (deaths under 1 year of age per 1,000 births) be 200, it is evident that 1,000,000 persons at birth (i.e. living at the *commencement* of the year in question) will be reduced to 800,000 during the year. The number commencing the second year is 800,000; taking the death-rate during that year of age as 65 per thousand living, the formula becomes $\frac{2,000-65}{2,000+65}$, or $\frac{1,935}{2,065}$, and, as already explained, the 800,000 living at the beginning of the second year will be reduced to $\frac{800,000}{1} \times \frac{1,935}{2,065}$, or 749,637, at its close. In like manner are determined the survivors at the end of the third, fourth, and fifth years. After the fifth year it is usual to proceed by five-yearly periods, but the method is substantially the same. Suppose, for instance, that we have already found that of the million only 700,000 survive at the end of the fifth year; and that the mean annual death-rate among persons aged 5 to 10 years is 6·5. This death-rate is assumed to be true of each of the five years, hence the formula of reduction *for each year* is $\frac{2,000-6{\cdot}5}{2,000+6{\cdot}5}$, and for the *five* years $\left(\frac{2,000-6{\cdot}5}{2,000+6{\cdot}5}\right)^5$. At the end of the tenth year, therefore, the 700,000 will have become reduced to $700,000 \times \left(\frac{2,000-6{\cdot}5}{2,000+6{\cdot}5}\right)^5$ —which, by the aid of logarithms, is readily found to be 677,615.

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* In other words, "the number of the living in any year of their age is an arithmetical mean proportional between the numbers that annually enter upon and that annually complete that year" (Milne, quoted by Farr). An earlier hypothesis (De Moivre's) assumed that the numbers living decreased in arithmetical progression down to nothing at the age of 86 years.

The process is repeated for each quinquennium until no more survivors are left.

If decennial be substituted for quinquennial periods, the annual death-rate D must be calculated for the ten-year age-period as a whole, and the formula will be $\left(\frac{2,000-D}{2,000+D}\right)^{10}$.

A life-table traces the history of a hypothetical generation which lives through each period of its life under the conditions that attend each such period during the era under examination. It eliminates the disturbing influence of a variable birth-rate and migration-rate, which introduce many fallacies into any attempted estimation of longevity from mere death-rates in a changing population. A census return gives the numbers living at ages *between* certain fixed points; a life-table, on the other hand, shows the relative numbers surviving *at* certain points of time, or rather of age, and thus enables us to calculate the expectation of life at any such point.

The **expectation of life** at any age A is calculated by adding together the years of life lived through by the whole of the life-table population after that age, and dividing by the number of survivors at age A. Thus to find the expectation of life at 50 years of age in males according to the 1891-1900 life-table (Appendix v.), the first step is to add together the numbers surviving at each later age: this gives the number of complete quinquennia lived through=1,745,421. But in addition to the quinquennia which he completes, each of the 530,888 males surviving at age 50 lives through some portion of that quinquennium in which he dies. By a further application of Milne's principle this fraction is averaged as half a quinquennium, and hence we have to add 265,444 half-quinquennia to the 1,745,421 quinquennia. We thus get a total of 2,010,865 quinquennia or 10,054,325 years of future life; and this, divided among the 530,888 who are alive at age 50, gives the expectation of life as 18·9 years.

The expectation of life is somewhat greater among females than among males, at all ages. It is greatest in both sexes at about 3 years of age.

Seasonal variations.—Most diseases, and well-defined groups of diseases, have a fairly constant relation to season, and present characteristic curves of average seasonal mortality, subject, however, to variation in time and range in any given year.

Many of them have an obvious relation to heat and cold: thus there is a winter maximum in deaths from apoplexy and diseases of lungs, heart, and kidneys; and a summer maximum as regards diarrhœa, tabes mesenterica, and thrush. Scarlet fever, enteric fever, diphtheria, puerperal fever, erysipelas, and rheumatism have their maximum about November; smallpox and whooping-cough have a spring maximum; and so, too, have phthisis, "convulsions," gout, and laryngitis. Measles has a double seasonal curve with two maxima and two minima.

Cause of Death.	Mortality.	
	Greatest.	Least.
Smallpox	January to May.	Sept. and Oct.
Measles	(1) December. (2) June.	(1) September. (2) February.
Scarlet fever	October.	March to May.
Diphtheria	Nov., December.	May, June.
Whooping-cough	March, April.	Sept., Oct.
Enteric fever	November.	June.
Typhus	January.	September.
Erysipelas	Nov., December.	May to Aug.
Puerperal fever	November.	August.
Other deaths from childbirth	Dec., January.	June, July.
Diarrhœa	July (4th week), Aug. (1st and 2nd weeks).	Dec. to May.
Rheumatism	November.	August.
Alcoholism	July.	Dec. to Mar.
Gout	April.	September.
Phthisis	March, April.	September.
Apoplexy, paralysis	Dec. to March.	July, August.
Convulsions	March.	September.
Diseases of circulatory system	Nov. to January.	August.
Laryngitis	March.	Aug., Sept.
Bronchitis	January.	August.
Pneumonia	Jan. and March.	August.
Pleurisy	December.	August.
Kidney disease	Nov. to April.	June to Aug.
Old age	January.	June to Oct.
All causes	(1) Dec. to March. (2) July to August.	(1) June. (2) October.

There are also characteristic seasonal curves of mortality from all causes at certain ages :—

AGES.	MORTALITY.	
	Greatest.	Least.
0- 1	4th week in July to 2nd week in Aug.	April, May, June.
1- 5	(1) Feb. to April (2) July, August .	June, July. September.
5-20	December . .	July, August.
Over 20	December . .	August.

The mortality at ages from 5 to 20 shows only a slight excess at midwinter and a slight falling-off at midsummer. The position of the maximum and minimum points remains the same at all later ages, but a rapidly increasing sensitiveness to cold is manifested by a wider range of seasonal curve. Below 5 years of age a similar increase in sensitiveness to climatic conditions is found; but the greatest danger is from heat, not from cold. From 1 to 5 years the principal maximum occurs in the early spring, owing to seasonal prevalence of whooping-cough and measles; but there is also a distinct rise in July and August, due to diarrhœal diseases. Under 1 year of age this minor elevation becomes an enormous peak, corresponding to the diarrhœa maximum.

The mean seasonal mortality curves of six infectious diseases in London are shown in Fig. 77.

Occupation and mortality.—In tracing, from mortality data, the influence of occupation upon health, it is necessary to take into account not only the numbers employed, but also their sex- and age-distribution, and the inevitable selection of the more robust for certain kinds of employment, and the weaker for others.

Comparing the results of the 1901 census with the mean mortality of the three years 1900–2,

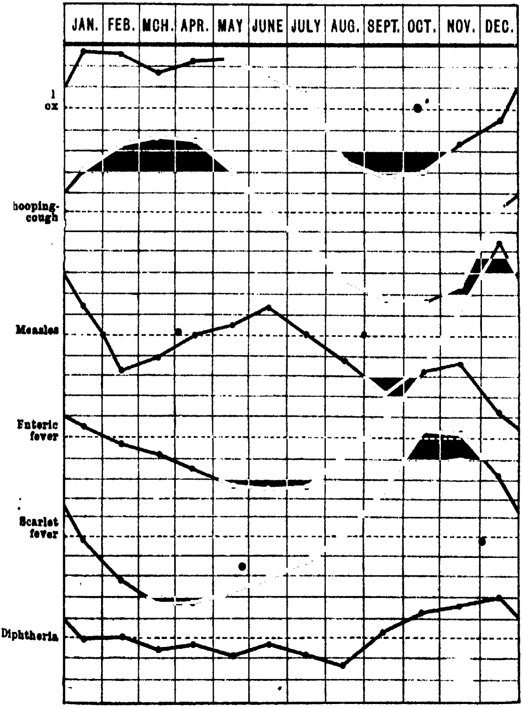

Fig. 77.—Seasonal curves of mortality (London). Mean of 40 years, except diphtheria (20 years) and enteric fever (12 years).

Each division corresponds to 10 per cent. above or below the mean annual mortality indicated by the dotted line.

Tatham showed that among the whole male population aged 25-65 there were 1,000 deaths per 71,005 living, corresponding to a death-rate of 14·1 (*see* Tables on p. 753).

For the four decennial age-periods thus covered the data were as follows :—

Age-period.	Standard population.	Annual death-rate.	Annual deaths in standard population.
25-35	26,259	6·38	168
35-45	20,407	10·94	223
45-55	14,748	18·67	275
55-65	9,591	34·80	384
25-65	71,005	14·08	1,000

In the same standard population the mortality from any specified cause can be calculated for each of the age-decennia and for the whole 25-65 age period; multiply the figure in column 4 by $\frac{\text{deaths from the specified cause}}{\text{total deaths}}$: the deaths to be taken into account being, of course, those of the age-period under consideration.

In like manner the smaller statistics of persons engaged in different occupations are dealt with, and in order to arrive at comparable results the standard age- (and sex-) distribution has to be observed. Thus, as regards the earthenware manufacture it is ascertained from the census returns how many male potters are living at each of the four age-decennia between 25 and 65; and from the death returns what is the annual number of deaths among male potters at each age-decennium. It is then easy to calculate the annual number of deaths among a standard population of 71,005 of potters—26,259 aged 25-35, 20,407 aged 35-45, 14,748 aged 45-55, and 9,591 aged 55-65. It is found to be 1,493, as compared with 1,000 for "all males." These are

COMPARATIVE MORTALITY ACCORDING TO OCCUPATION, AMONG MALES 25-65 YEARS OF AGE

England and Wales. 1900-1-2.	Alcoholism.	Gout.	Cancer.	Phthisis.	Bronchitis.	Pneumonia.	Liver diseases.	Bright's disease.	Plumbism.	All causes.
ALL MALES	23	2	68	186	57	90	27	35	1	1000
Agriculturists	7	1	50	85	22	49	13	18	—	602
Fishermen	12	—	65	100	27	62	16	20	—	967
Cotton manufacture	12	1	72	197	92	109	17	38	—	1114
Wool manufacture	7	—	64	159	56	83	24	50	—	984
Coal miners	5	—	53	89	79	86	17	12	—	885
Coal heavers	29	1	57	213	91	157	18	42	—	1221
Tin miners	—	—	69	816	206	81	12	50	—	2131
Lead miners	6	—	66	324	53	84	19	19	—	1206
Glass manufacture	7	4	71	283	132	104	23	53	8	1260
Earthenware ,,	8	—	74	285	253	105	21	33	10	1493
Plumbers	13	8	73	213	57	85	21	74	23	1114
Cutlers	13	2	72	533	132	136	22	51	—	1566
File-makers	14	—	57	387	114	151	15	134	56	1700
Printers	8	3	65	300	47	64	24	42	2	994
Tailors	15	3	77	246	61	68	26	42	—	1027
Drapers	16	1	56	203	22	59	30	35	—	845
Grocers	11	1	54	125	30	43	32	37	—	729
Bakers	13	2	74	165	53	79	32	33	—	—
Butchers	34	5	74	182	58	96	60	46	—	1148
Brewers	47	5	119	248	96	96	73	43	—	1393
Innkeepers	111	11	74	271	57	147	201	87	—	1781
Costermongers	59	1	93	554	165	177	40	55	—	2007
Dock labourers	50	2	76	308	137	187	22	41	—	1481
Chimney sweeps	48	4	152	284	100	136	32	23	—	1345

The following list shows the comparative mortality figure, calculated in the same way, for a number of other occupations:—

ALL MALES	1,000	Shoemakers	984
Clergy	524	Commercial travellers	988
Gardeners	563	Medical men	952
Teachers	665	Shopkeepers generally	978
Hosiery manufacture	921	Law clerks	970
Lace workers	950	Hairdressers	1,196
Tanners	774	Hatters	1,137
Artists	828	Musicians	1,261
Lawyers	750	General labourers	2,235
Blacksmiths	987		

comparable figures; in the same way comparable data as to mortality from phthisis and other special causes can be obtained for each occupation. (*See* Tables on p. 753.)

Phthisis and respiratory diseases cause a high mortality among debilitated persons, especially those exposed to weather, to hot or impure air, and to certain forms of dust. Hence the mortality from these causes is high among costermongers, cutlers, file-makers, potters, printers, and highest of all in Cornish tin-miners. The comparatively low mortality from phthisis among coal-miners may be attributed to the particles of coal being comparatively free from sharp angles and hence less irritating than stone or metallic dust (*Hirt*). The same immunity from phthisis has been observed among coal-miners in other countries, but it must not be forgotten that the nature of the employment excludes weakly persons, and that coal-mines are well ventilated. The death-rate is highest in occupations in which the workman is exposed to poisons (such as alcohol and lead), hard dust, and inclement weather, without opportunity of exercise; in open-air work combined with exercise and in properly supervised industries the mortality is low (*Bertillon*).

Nervous diseases cause excessive mortality in occupations associated with alcohol or lead; the most fatal occupations in this respect are those of innkeepers, glass-makers, file-makers, and lead-workers. The incidence of gout and of fatal kidney disease is very similar. Mortality from diseases of the liver is in the main associated with mortality from alcoholism, both being high, for example, among commercial travellers, butchers, brewers, and innkeepers.

Diseases of the circulatory system are most fatal among costermongers, cabmen, brewers, publicans, potters, cutlers, file-makers, and workers in glass.

The comparative mortality figures tend to establish a relation between intemperance and diseases of the heart, liver, kidneys, and nervous system, and also phthisis and gout. Lead poisoning, similarly, is seen to be associated with diseases of the kidney, heart, and nervous system, and also with gout.

Value of statistical series and averages.—The *mean* or *average* of a series of numbers is a number which lies between the greatest and least of these, and stands in a definite dependence upon the whole of the series (*Radicke*). There are several kinds of means. Thus, if the series consists of four numbers—namely, a, b, c, and d—we have

The *arithmetic* mean, or simple average, $\dfrac{a+b+c+d}{4}$.

The *geometric* mean, $\sqrt[4]{a\,b\,c\,d}$.

The *harmonic* mean, $\dfrac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$.

The *quadratic* mean, $\sqrt{\dfrac{a^2+b^2+c^2+d^2}{4}}$.

When the terms of the series are equal, all kinds of means are also equal; but if otherwise, the quadratic is the highest, then the arithmetic, geometric, and harmonic, in the order stated.

The **simple average**, or arithmetic mean, is by far the most generally adopted, and mainly in three classes of cases:—

1. *As a pure average;* for example, the average age of a number of persons. The terms are exact, and the "mean" has no significance as regards any individual. Thus, the ages of ten persons whose deaths were attributed to diarrhœa might be 1, 1, 1, 1, 71, 71, 1, 1, 1, 71; and those of ten who died from enteric fever 17, 18, 26, 29, 25, 20, 16, 19, 24, 26. These two series have nothing in common as regards

the individuals, but the average of each is 22. The mean temperature of a day or year is a simple average of the observations which are taken into account. Similarly, if we mix together equal volumes—say, an ounce of each —of four saline solutions containing respectively 10, 20, 30, and 40 grains of salt per ounce, the whole will contain 25 grains per ounce.

2. *As a probable true value of a definite quantity.* —Given two results equally likely to occur, the frequency of the one becomes more and more certainly equal to that of the other, in proportion as the number of observations increases. If a coin be tossed 1,000 times, it is improbable that heads will turn up much more or much less than 500 times; but with only 10 trials, there is little certainty of approximate equality. If in a given series of measurements of a fixed quantity (an angle, for instance) the errors of experiment are exactly as likely to be in excess as in deficiency, these errors will neutralize each other if we take the mean of a sufficiently large number of observations. An error of magnitude x in a single observation will affect the mean to the extent $\frac{x}{10}$ in a series of ten observations, but only $\frac{x}{1,000}$ in a series of a thousand terms. The more extended the series, the greater the probability of accuracy, which increases as the square root of the number of observations.

If the measurements are of equal precision, a closer but less simple approximation to the probable true value sought may be obtained by adopting the principle of *least squares*: that is, by finding such a mean value that the sum of the squares of the residual errors of the observations shall be a minimum.

3. *As a probable value of a variable quantity* determined under average conditions; for example, the

average daily excretion of urea, as determined by a series of more or less exact measurements under varying conditions as to food and exercise. In vital statistics absolutely fixed points are of rare occurrence, and most of the problems belong strictly to this class.

It may be important to determine the value of a series of observations; that is, how far the mean is a trustworthy approximation to the true value sought. As already explained, the value of a series increases with the number of observations, and with their equality. Another test is that of "*successive means.*" For this purpose we take the mean of the first two terms $\left(\frac{a+b}{2}\right)$, of the first three $\left(\frac{a+b+c}{3}\right)$, of the first four $\left(\frac{a+b+c+d}{4}\right)$, and so on. These "successive means" may vary sharply at first; but presently the first figure becomes stationary; then the second; and finally, if the series is sufficiently extended, the later successive means cease to vary materially. If the successive means, carried to the end of the series of terms, do not attain the required degree of constancy, the series is too short.

A further criterion is the **determination of the error**; that is, the divergence of the individual terms of the series from its mean. The *mean error in excess* and the *mean error in deficiency* are simply the arithmetic means of the errors of those terms which fall respectively above and below the mean of the series. The *mean error of the series* is the average of the mean errors in excess and deficiency. The greater the mean error, the greater is the need for an extended series in order to compensate for the uncertainty of each observation. Radicke prefers to adopt the quadratic mean error rather than the arithmetic, described above, since the former increases more rapidly with the inequality of the terms.

Multiplying the mean error by 0·6745 or $\frac{2}{3}$, we get the *probable error*, so called because it is probable that, if the series were prolonged indefinitely, the errors would as often exceed as fall short of this quantity.

The *maximum error*, whether in excess or deficiency, is useful as showing the *possible* error of a limited number of observations. Another way of estimating the error is to determine the *error of mean square*. In a series of n terms, Q being the quadratic mean and A the arithmetic mean, the error of mean square is $\frac{Q-A}{(n^2-n)}$.

The value of a series increases as the proportion of the error (of whatever kind) to the mean diminishes. The relative values of two or more series vary inversely as the square of their probable errors.

Statistics are often presented in bulk, and the same question of sufficiency arises. For instance, out of 6,288 reported cases of scarlet fever, 2,861 are at ages under 5 years; are these numbers sufficiently great to warrant the conclusion that the proportion, 45·5 per cent., is approximately constant? Such data are really the sum or average of suppressed series, and their value is proportionate to the square root of their magnitude. Poisson proposed to measure the liability to error thus: If, of μ observations, m are in one category and n in other categories, and $m + n = \mu$, then the true proportion of the m category to the total μ lies between $\frac{m}{\mu} + 2\sqrt{\frac{2mn}{\mu^3}}$ and $\frac{m}{\mu} - 2\sqrt{\frac{2mn}{\mu^3}}$; that is, within a possible range of $4\sqrt{\frac{2mn}{\mu^3}}$. In the instance in point the range is $4\sqrt{\frac{2 \times 2{,}861 \times 3{,}427}{(6{,}288)^3}}$, or about $\frac{36}{1{,}000}$. Hence the indicated proportion, 45·5 per cent., is liable to a range of error of 3·6 per cent.; from 43·7 to 47·3.

It may also be possible to divide the total μ into two or more fairly equal parts, and thus ascertain if the proportion $\frac{m}{\mu}$ is approximately constant in each. Such constancy would tend to show that the proportion is a fixed quantity, and not a mere average.

The preceding remarks have reference mainly to series that are intended to show by their mean some true fixed quantity. Sometimes they are used for a different purpose—namely, the exhibition of progressive changes or fluctuations. Here the general considerations as to magnitude still apply, but the determinations of "error" have no significance except in regard of the individual terms of the series. It is often convenient, for the purpose of comparing the fluctuations of different series, to adopt *Buchan and Mitchell's method*—namely, to state each term of a series as a percentage of the arithmetic mean of the series. In this way all series, whether the terms are large or small, are reduced to the same scale, and their true differences and resemblances can be seen at a glance. The curves in Fig. 77 (p. 751) may serve as an example.

If the terms of a series are based upon scanty statistics, the accidental irregularities may be so great as to obscure the true curve. Some degree of this is evident in respect of diphtheria in Fig. 77. A clearer indication of the general outline may in such cases often be obtained by *Bloxam's method*—that is, by substituting for each term the mean of three adjoining terms. Thus in a series a, b, c, d, e, f, g, etc., we should substitute (a), $\frac{a+b+c}{3}$, $\frac{b+c+d}{3}$, $\frac{c+d+e}{3}$, etc. This treatment is, of course, arbitrary, and curves so constructed are not to be regarded as exact in detail.

APPENDICES

I. STANDARDIZED DEATH-RATES AT AGES, ENGLAND AND WALES

AGES.	Males.						Females.					
Ten years ended	1860	1870	1880	1890	1900	1910	1860	1870	1880	1890	1900	191
All Ages	21·9	22·3	21·5	19·7	19·2	16·3	20·6	20·4	19·3	17·6	17·0	14·
0— 5	72·4	73·5	68·4	61·6	62·7	50·0	62·7	63·7	58·3	51·9	52·8	41·
5—10	8·5	8·2	6·7	5·3	4·3	3·5	8·4	7·8	6·2	5·3	4·4	3·
10—15	4·9	4·5	3·7	3·0	2·4	2·1	5·1	4·5	3·7	3·1	2·6	2·
15—20	6·7	6·2	5·3	4·3	3·8	3·1	7·4	6·6	5·5	4·4	3·7	2·
20—25	8·8	8·5	7·4	5·7	5·1	4·2	8·5	8·0	6·8	5·5	4·5	3·
25—35	9·6	9·9	9·3	7·8	6·8	5·6	9·9	9·7	8·6	7·4	6·1	4·7
35—45	12·5	13·5	13·8	12·4	11·5	9·2	12·2	12·1	11·6	10·6	9·6	7·
45—55	18·0	19·3	20·1	19·4	18·9	16·2	15·2	15·6	15·6	15·1	14·7	12·
55—65	30·9	33·1	34·9	34·7	34·9	31·8	27·9	27·9	28·7	28·5	28·4	24·
65—75	65·3	67·1	69·7	70·5	70·4	64·8	58·7	59·1	61·0	60·4	60·7	53·
75—85	146·7	147·2	150·8	146·6	146·1	137·7	134·5	134·9	135·4	130·6	130·6	119·
Over 85	308·2	315·0	327·4	305·8	286·8	270·2	288·9	285·1	296·4	270·8	261·4	250

II. POPULATION, ENGLAND AND WALES

Census.	Population.	Rate of Decennial Increase.	Females per 100 Males.	Density.	
				Per Square Mile.	Per Inhabited House.
1861	20,066,224	11·9	105·3	344	5·4
1871	22,712,266	13·2	105·4	390	5·3
1881	25,974,439	14·4	105·5	445	5·4
1891	29,002,525	11·7	106·4	497	5·3
1901	32,526,075	12·2*	106·9	558	5·2
1911	36,075,269	10·9	106·8		

* Highest (23·1) in urban districts of 50,000 to 100,000, diminishing in each direction to 9·8 in those over 250,000 and to 4·6 in those under 3,000.

III. AGE- AND SEX-DISTRIBUTION OF POPULATION PER MILLION, ENGLAND AND WALES

CENSUS 1901

Age-periods.	Males.	Females.	Total.	Urban.*	Rural.
0— 5	57,039	57,223	114,262	114,348	113,978
5 —10	53,462	53,747	107,209	105,555	112,760
10—15	51,370	51,365	102,735	101,147	108,897
15—20	49,420	50,376	99,796	101,080	95,489
20—25	45,273	50,673	95,946	100,291	81,870
25—35	76,425	85,154	161,579	167,597	141,890
35—45	59,394	63,455	122,849	124,282	118,039
45—55	42,924	46,298	89,222	88,368	92,086
55—65	27,913	31,828	59,741	56,642	70,139
65—75	14,691	18,389	33,080	29,502	45,080
75—85	5,080	7,010	12,090	10,102	18,758
Over 85	552	939	1,491	1,186	2,514
All Ages	483,543	516,457	1,000,000	1,000,000*	1,000,000†

* Males, 479,444; females, 520,556.
† Males, 497,293; females, 502,707.

IV. BIRTH-RATES AND DEATH-RATES, ENGLAND AND WALES

Decennium.	Birth-Rate.	Births of Males per 100 Births of Females.	Death-Rate.			Infant Mortality.
			Male.	Female.	Total.	
1851—1860	34·1	104·6	23·1	21·4	22·2	154
1861—1870	35·2	104·2	23·7	21·4	22·5	154
1871—1880	35·4	103·8	22·7	20·1	21·4	149
1881—1890	32·4	103·7	20·3	18·1	19·1	142
1891—1900	29·9	103·6	19·3	17·1	18·2	153
1901—1910	27·2	103·8	16·4	14·4	15·4	128

V. English Life-Table, based upon the Mortality Statistics of 1891-1900 (Tatham)

Age.	Males.				Females.			
	Survivors at each age, out of 1,000,000 born.	Expectation of Life.			Survivors at each age, out of 1,000,000 born.	Expectation of Life.		
		1891-00	1881-90	1838-54		1891-00	1881-90	1838-54
0	1,000,000	44·1	*43·7*	*39·9*	1,000,000	47·8	*47·2*	*41·8*
1	828,136	52·2	*51·0*	*46·6*	859,342	54·5	*53·2*	*47·3*
2	784,090	54·1	*53·0*	*48·8*	816,810	56·3	*55·2*	*49·4*
3	767,754	54·3	*53·3*	*49·6*	800,357	56 5	*55·5*	*50·2*
4	757,631	54·0	*53·1*	*49·8*	789,683	56·2	*55·3*	*50·4*
5	750,281	53·5	*52·7*	*49·7*	782,144	55·8	*54·9*	*50·3*
10	734,299	49·6	*49·0*	*47·0*	765,267	52·0	*51·1*	*47·7*
15	725,373	45·2	*44·5*	*43·2*	755,499	47·6	*46·5*	*43·9*
20	711,714	41·0	*40·3*	*39·5*	741,766	43·4	*42·4*	*40·3*
25	693,894	37·0	*36·3*	*36·1*	725,386	39·4	*38·5*	*37·0*
30	673,200	33·1	*32·5*	*32·8*	705,819	35·4	*34·8*	*33·8*
35	648,169	29·2	*28·9*	*29·4*	682,147	31·5	*31·2*	*30·6*
40	615,964	25·6	*25·4*	*26·1*	653,014	27·8	*27·6*	*27·3*
45	577,010	22·2	*22·1*	*22·8*	619,184	24·2	*24·0*	*24·1*
50	530,888	18·9	*18·8*	*19·5*	580,320	20·6	*20·6*	*20·7*
55	475,849	15·8	*15·7*	*16·4*	533,105	17·2	*17·2*	*17·4*
60	409,518	12·9	*12·9*	*13·5*	473,037	14·1	*14·1*	*14·3*
65	332,344	10·3	*10·3*	*10·8*	398,209	11·3	*11·3*	*11·5*
70	246,630	8·0	*8·0*	*8·4*	307,168	8·8	*8·8*	*9·0*
75	158,608	6·1	*6·1*	*6·5*	210,688	6·7	*6·7*	*6·9*
80	82,298	4·6	*4·5*	*4·9*	118,068	5·0	*5·0*	*5·3*
85	31,323	3·4	*3·3*	*3·7*	49,985	3·8	*3·7*	*4·0*
90	7,724	2·6	*2·4*	*2·8*	14,330	2·9	*2·7*	*3·0*
95	1,059	1·9	*1·7*	*2·2*	2,494	2·2	*2·0*	*2·3*
100	68	1·5	*1·2*	*1·7*	241	1·8	*1·5*	*1·8*

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Printed by Cassell & Co., Limited, La Belle Sauvage, London, E.C.4.
10.919